THE TIRE PROJECT

FURTHER REVIEW OF PYROLYSIS/INCINERATION PROJECTS THAT MET THE TECHNICAL COMMITTEE EVALUATION CRITERIA

Conducted by:

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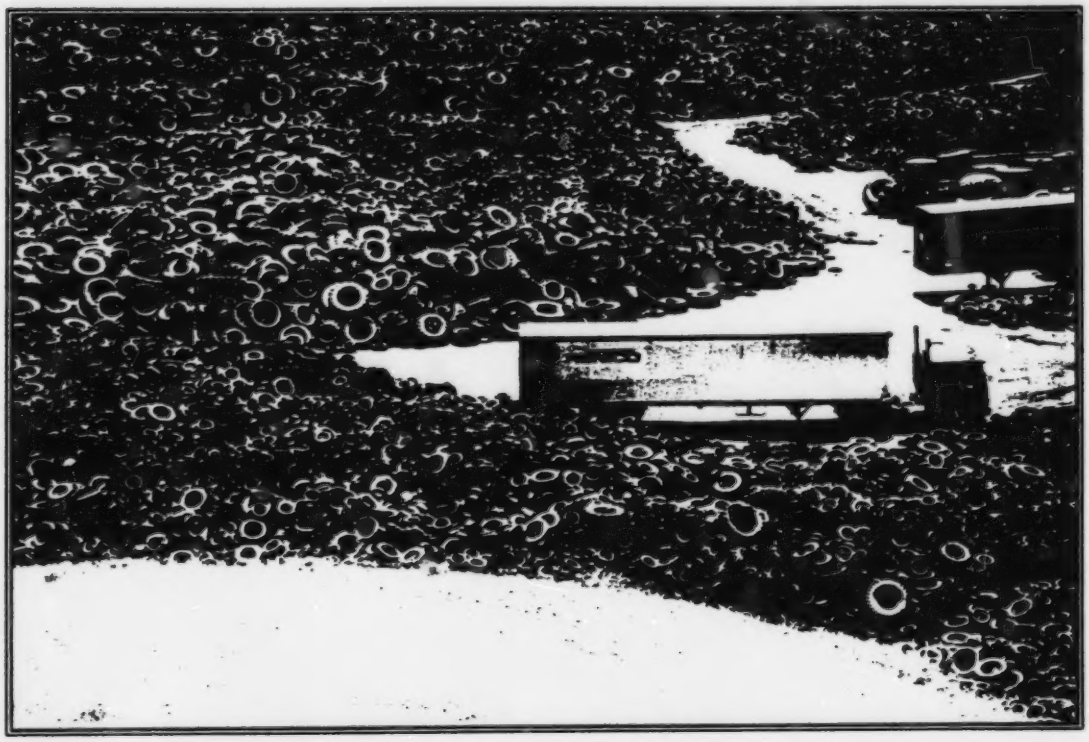
THE SIZE OF THE PROBLEM

VIEW OF THE TIRE PILE NEAR MODESTO CALIFORNIA. THE PILE ORIGINALLY CONTAINED 15 MILLION TIRES, AND HAS NOW BEEN REDUCED TO APPROXIMATELY 3.5 MILLION.



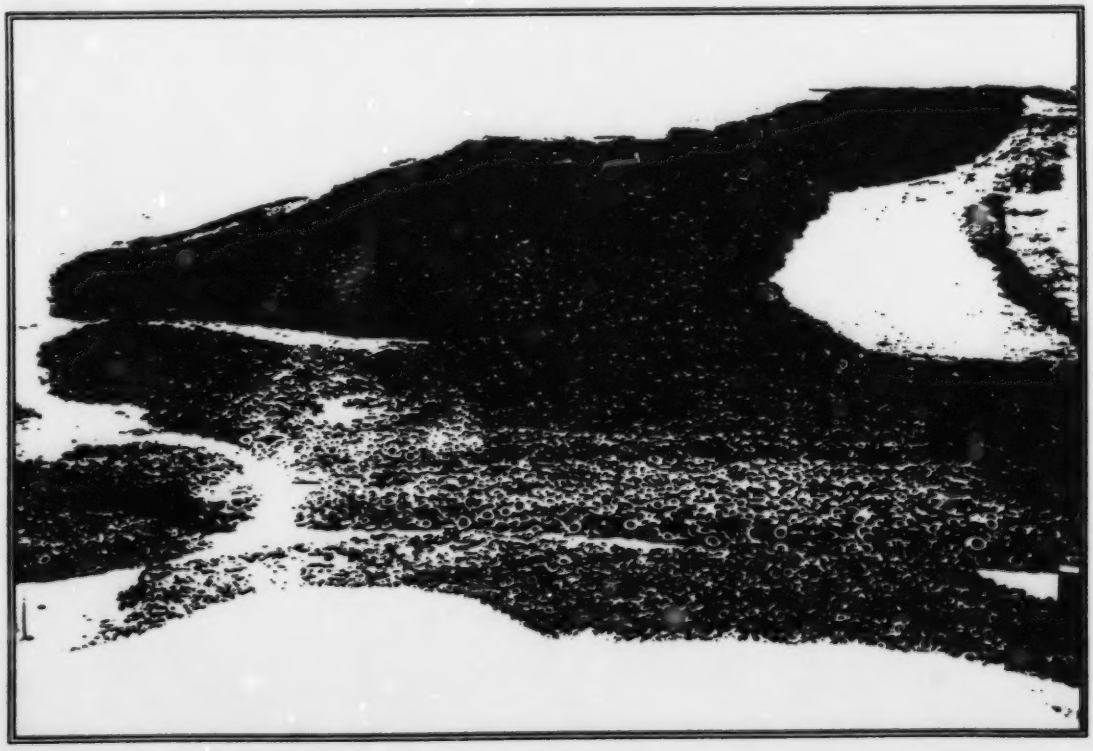


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CHART 1-1 SUMMARY OF REVIEWED PROPOSALS

PROPONENT	PROCESS	PRODUCTS	DISPOSITION OF PRODUCTS	TIRES PER YEAR-MILLIONS	CAPITAL COST-$MILLIONS	TECHNICAL RISK	MARKET RISK	ENVIRON-MENTAL RISK	COMMER-CIAL STATUS
LAFARGE	CEMENT PLANT	HEAT	DISPLACES PART OF REGULAR FUEL	1.0	PHASE 2- 1.8	LOW	LOW	LOW	YES
		METAL	METAL GOES INTO CEMENT						
INLAND	CEMENT PLANT	HEAT	DISPLACES PART OF REGULAR FUEL	0.66	PHASE 2- 1.5	LOW	LOW	LOW	YES
		METAL	METAL GOES INTO CEMENT						
PACIFIC	POWER PLANT	ELECTRICITY	ELECTRICAL GRID	1.5	PHASE 2- 17.5	LOW TO MODERATE	LOW	LOW	YES
		STEAM	GREENHOUSES ETC						
		METAL	SCRAP METAL						
		LIME/ASH	CONCRETE/CEMENT						
WORTHING	PYROLYSIS	FUEL OIL, GAS	FUEL	0.31	PHASE 2- 0.7	MODERATE	MEDIUM	LOW	NO
		CARBON	FUEL						
		METAL	SCRAP METAL						
ENERWASTE	PYROLYSIS	FUEL OIL, GAS	FUEL	1.5	PHASE 1- 2.5 PHASE 2- 8.5	MODERATE	HIGH	LOW	LIMITED
		CARBON	CARBON BLACK, ACTIVATED CARBON						
		METAL	SCRAP METAL						
HUSKY	H-RUBBER (FORM OF PYROLYSIS)	GAS OIL, GAS	FUEL	2.5	PHASE 1- 5.4 PHASE 2- 25.5	MODERATE	HIGH	LOW	NO
		CARBON	CARBON BLACK, ACTIVATED CARBON						
		METAL	SCRAP METAL						

1. EXECUTIVE SUMMARY

In response to a request by Alberta Environment, the six used tire conversion processes identified in Chart 1-1 were evaluated in accordance with the key purpose specified in RFP #43276- "to assess the relative merits of processes and technologies to determine the most economically and environmentally sound methods of solving the scrap tire disposal problem".

The Reviewers have evaluated the economic, technical and environmental aspects of these six projects.

1. Lafarge and Inland offer the quickest and lowest cost method to dispose of tires over the next three - five year period. This time period would be sufficient to confirm previous Canadian and U.S.A. test results that using tires as part of the energy and materials required by cement plants does not materially affect the emissions from the plants. Recently practised just-in-time delivery of whole tires transported in closed vans would remove concern over the storage of tires in sensitive geographic regions. Selection of any of the other projects would result in significantly higher overall tire disposal costs to the public.

A recent report to the California Legislature reached similar conclusions. This report recommends support be provided for the use of tires as fuel for cement kilns, noting that the short capital payback period permits other uses to develop when market forces dictate. The report states that:

> "Emission tests at two California cement plants burning waste tires with coal fuel showed no appreciable difference in toxic air contaminant emissions when compared to burning coal fuel only. The use of tires by cement kilns is a method with existing technology that could be quickly implemented and has the potential to eliminate all of the waste tires stockpiled and generated" [1]

The economic superiority of cement kilns for tire disposal was also highlighted in a newsletter devoted to scrap tire disposal:

> "No green field plant, pyrolysis or otherwise, can compete with an already capitalized facility".[2]

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[1]Tires as a Fuel Supplement: Feasibility Study, Report to the Legislature, January 1992, California Integrated Waste Management Board.

[2]Scrap Tire News, Vol.5, No.12, December, 1991, Pg.4.

2. Electric power production from tires as proposed by Pacific is a commercial process. A dedicated plant was built near Modesto, California at the site of a very large stockpile of used tires, originally containing about fifteen million tires. The combination of no transportation costs, the ability to feed whole tires, and high electricity prices have apparently provided an acceptable rate of return. Pacific are proposing a technical advance by using fluid bed combustion, which slightly increases the technical risks of this approach. The need for shredding adds somewhat to the costs. Assuming contracts are in place in advance, the market risks for power generation would be negligible.

3. Pyrolysis processes, or modifications thereof, submitted by Worthing, Enerwaste, and Husky provide the highest degree of product upgrading, particularly with respect to carbon black, representing about one third of the original tire weight. Husky's process, operated under hydrogen pressure, produces the highest product values, but at a substantially higher cost. Enerwaste through its connections with Conrad Industries has a good base of experience to enter the pyrolysis field. Worthing has an operable pilot plant which could be used to provide a quick entry for a relatively small operation.

Tire pyrolysis is an unproven process and has significant technical risk. Considerable market development work would be needed to capture the high-value end of the carbon black market. The Reviewers were unable to locate a fully commercial tire pyrolysis project in the United States, although a well designed demonstration plant was inspected in the State of Washington. This situation is confirmed in the previously mentioned California report which states:

> "Tire pyrolysis in not yet commercialized in the United States. Major reasons for this include the high capital costs associated with process equipment, lack of markets, and relatively low value of the products, especially carbon black."

The Reviewers believe that the value of the carbon black can be substantially increased through upgrading, but this would require dedicated research and market development efforts. Due to the potential of pyrolysis to handle a variety of waste products, the Reviewers recommend that process and marketing efforts on pyrolysis be included in research programs of the appropriate Alberta research institutions.

4. None of the projects evaluated by the Reviewers appear to have serious environmental risks. Close monitoring of species such as chromium and zinc, in addition to all the legislated environmental emissions, would be required.

5. The capital costs involved in the plants proposed by Husky, Pacific, and Enerwaste are such that loss of a sufficient supply of tires would be catastrophic in that there would be no revenue to meet the ongoing capital charges, depreciation and fixed operating costs. For the cement plants, loss of tire supply in the first three years would be serious but the amount of capital at risk would be relatively small. After the third year the risk for these companies would be negligible because they can readily switch to 100% natural gas fuel.

6. The Proponents have requested financial assistance in the form of an ongoing tire disposal fee, and in two cases, requested access to tire fee revenue in advance of the start-up of the processing plant (Phase 2). The Reviewers have calculated the tire fee required to cover the difference between the revenue from the sale of products and the sum of the costs of capital, collection, transportation, shredding and operation. The real return on capital was set at 15% (after inflation), whether it was provided by the Proponent or provided by the public through the provision of tire fee revenue in advance. The following table summarizes the financial assistance requirements. For Lafarge and Inland, it would be appropriate to negotiate a tire fee for three to five years, while for Pacific, Enerwaste and Husky, such a fee would have to be set for the 20-year life of these projects.

PHASE	PROJECT	ACCESS TO EARLY TIRE FEE CAPITAL REQUESTED BY PROPONENT- $MILLION	ONGOING TIRE FEE REQUESTED BY PROPONENT- $ PER TIRE	TIRE FEE CALCULATED BY REVIEWERS ON A TOTAL PROJECT BASIS- $ PER TIRE
PHASE 2 ONLY	LAFARGE	C	$1.00	$0.74 [1]
	INLAND	C	$2.35	$1.31 [1]
	PACIFIC	C	$2.89	$2.39
PHASE 1 & 2	LAFARGE	C	$2.50	$2.24 [1]
	WORTHING	C	$3.50	$4.03 [1]
	ENERWASTE	$10.5	$3.50	$2.45
	HUSKY	$15.0 - $22.5	$2.00 - $3.00	$3.33

[1] 3-year capital pay-back; all others at 20 years

2. BACKGROUND

Dr. C.W. Bowman and Dr. E.L. Tollefson were requested by Alberta Environment to carry out detailed assessments of six proposals submitted in response to RFP #43276, within the pyrolysis/incineration classification. The Reviewers were also requested to assess four other proposals that had failed to meet the criteria set by the Technical Committee, within this same general classification, to determine if a more detailed examination were warranted.

For the six primary proposals (Chart 2-1), the reviewers undertook:

- a detailed review of each proposal, as submitted;
- the compilation of a chart comparing each proposal with respect to 15 activity/result features;
- the preparation of a list of questions to ask each Proponent;
- a meeting with each Proponent to obtain responses to the questions. At this meeting, the Proponent provided an update on the proposal in various areas, including plant throughput, tire pre-treatment, processing techniques, product values etc.
- site visits to facilities owned by three of the Proponents;
- site visits to three facilities in the U.S.A., involving power generation, cement manufacture and pyrolysis technologies;
- an information exchange meeting with the Ministerial Advisory Committee of the Tire Project; and
- the preparation of a report on findings, options and general observations arising from this assessment process;

CHART 2-1 PROPONENTS

Full Name of Proponents	Reference Name in this Report
Lafarge Canada Inc., Systech Environmental Corporation	Lafarge
Inland Cement Limited	Inland
Pacific Integrated Waste Systems Inc.	Pacific
Worthing Industries Inc., Roen Enterprises	Worthing
Enerwaste International Inc.	Enerwaste
Husky Oil Ltd., CANA Limited	Husky

3. MEETINGS WITH PROPONENTS AND SITE INSPECTIONS

The Reviewers met with representatives of each Proponent in their offices, and in three cases inspected their associated facilities. Visits were subsequently made to three operations in the United States.

Brief descriptions of these meetings are presented below, with full details in Appendices A and B.

MEETING NO. 1 - June 1, 1992
with Pacific Integrated Waste Systems Inc., Calgary
Attendees: Hugh Ham
Bryan Scott
Mayor Al Gehring from the Town of Trochu
C.W. Bowman
E.L. Tollefson

Pacific proposes to construct a plant to convert 1.5 million tires per year to electric power to feed into the Alberta electrical grid. They plan to use a fluidized bed technology under development in Coeur d'Alene, Idaho.

MEETING NO. 2 - June 2, 1992
with Worthing Industries Inc., Calgary
Attendees: Dr. Peter Fransham - Vice-President
Harvey Poon - C.E.O.
C.W. Bowman
E.L. Tollefson

Worthing proposes to operate a pyrolysis unit to convert 310,000 tires per year as granular material to gas, oil, carbon and metals.

MEETING NO. 3 - June 2, 1992
at the Lafarge Canada Inc. Plant at Exshaw
Attendees: Claude Bertrand, Director, Co-processing and Environment, Technical Services
Christopher Bart, New Business Development, Systech
H.L. Youngsblood, President
Mike Pawlicki, Manager of Environmental Affairs
C. Shekhar, Process Manager, Richmond Cement Plant

Bernie Bonneau, Vice-President, Operations
Jean D. Catillon, Plant Manager
C.W. Bowman
E.L. Tollefson

Lafarge proposes to install an automatic loader to feed whole tires into its Exshaw No. 5 kiln at the rate of approximately 1.0 million per year.

MEETING NO. 4 - June 3, 1992
with Enerwaste International Inc., Calgary
Attendees: Bruce Sinclair,
Nelson Bump
Camrose Mayor Norman Mayer
Dennis Twomey
C.W. Bowman
E.L. Tollefson

Enerwaste proposes to pyrolyse 50 tons per day of tires (1.5 M tires/year) to produce oil - 50%, carbon - 32%, gas - 10%, and steel - 7%.

MEETING NO. 5 - June 4, 1992
at the Inland Cement Limited Plant, Edmonton
Attendees: Vince Heron, Manager of Engineering
Dave Pickerell, Environmental Engineer
David Selleck, Regional Vice-President, Environmental Management
Keith Meagher, Process Superintendent
Bob Rymes, Plant Chemist
C.W. Bowman
E.L. Tollefson

Inland proposes to feed 660,000 whole tires per year to their cement kiln to provide energy, displacing some gas as feed to the kiln and incorporating the steel from the tires into the cement product.

MEETING NO. 6 - June 9, 1992
with Husky Oil Ltd.- CANA Limited, Carillon Room, Legislature Building, Edmonton
Attendees: Peter C. Quinn, President HRI Inc.
Geoffrey E. Dennis, Manager, Technical Services HRI Inc.
John D. Simpson, President CANA Limited
C.W. Bowman
E.L. Tollefson

Husky proposes to use their service station network to collect waste tires. Tires would be shredded into chips. The chips would be dissolved in oil and treated with hydrogen at approximately 1000 psig at 750°F. A carbon product of higher value is expected along with gas, oil and metal fractions.

MEETING NO. 7 - June 10, 1992
with the Modesto Power Plant, Modesto, California
Attendees: Douglas Tomison, Plant Manager
Bryan Scott, Pacific Integrated Waste
C.W. Bowman
E.L. Tollefson

The plant converts 5.0 million whole tires per year and produces 15 MW electric power, of which 12.4 MW is sold. No plume was observed from the stack. The plant has won awards for conversion of waste tires to energy while meeting stringent emission guidelines.

MEETING NO. 8 - June 11, 1992
at the Calaveras Cement Plant, Redding, California
Attendees: Bill Siemering, Plant Manager
Michael Bungay, CemEnergy
C.W. Bowman
E.L. Tollefson

The plant converts 1.7 - 1.8 million whole tire/year and meets state and national guidelines for cement plants. The plant is supplied with tires by CemEnergy. The plant is similar to that of Inland Cement, Edmonton. There was no evidence of a plume from the stack.

MEETING NO. 9 - June 12, 1992
with Conrad Industries Inc., Centralia, Washington
Attendees: William F. Conrad, President
Philip Bridges, Vice-President
C.W. Bowman
E.L. Tollefson

This plant is similar in design to the one proposed by Enerwaste International Inc. The plant handles one ton per hour of shredded tires (800,000/year). Although described as a "commercial" plant, it appears to serve primarily as a versatile pilot plant. Tires represent 80% of the feed and the balance is comprised of other wastes.

4. COMPARISON OF PROCESSES

Chart 4-1 provides a summary of these six projects with reference to 15 activity areas, including tire collection, transportation, processing, economics, and environmental aspects.

Chart 4-2 identifies the principal chemical reactions involved in each operation.

Flow-charts of each process are provided in Appendix C.

These comparisons were prepared during the initial review of the submitted proposals, and augmented at the time of the meetings with each Proponent.

Summary Comments

The use of waste tires as a feedstock for cement plants is a proven commercial process. The Calaveras cement plant in Redding California has used tire feed since 1989, and has been feeding whole tires since September 1991. It is currently using about 1.7 million tires per year. The tires provide about 20% of the total energy requirement and the steel in the tire provides a portion of the required iron. Tires contain more than 1% sulphur. Sulphur dioxide, produced by oxidation of the sulphur, is removed from the combustion gases by reaction with lime produced from limestone, one of the major raw materials used in cement manufacture. Cement plants in the United States have active programs to reduce their costs by using various lower value fuels and waste products to supply part of the energy requirements. Canadian cement plants will have to follow the same course to remain competitive by international standards.

There are a small number of electrical power plants operating in the United States using tires as the feedstock. The 12.4 MW power plant near Modesto California burns whole tire feed, and since 1987 has reduced a stockpile of 15 million tires to about 3.5 million, as well as handling additional tires brought to the plant site. The plant meets emission requirements by removing particulates in a bag-house and removing SO_2 by passing the off-gas through an aqueous calcium hydroxide spray.

Through the combination of cement and power plants, California is

well on the way to solving its used tire stockpile problem. In fact, some of the plants are now concerned about future waste tire supply.

By contrast, used tire pyrolysis technology is not as well developed. The Reviewers were not successful in locating a fully commercial pyrolysis plant using tires as feedstock in the United States. A well designed demonstration plant in the State of Washington was inspected which was capable of using shredded tires. The developers are using the plant to test new feedstocks and to demonstrate the technology to potential licensees. Pyrolysis produces gaseous and liquid hydrocarbon fuels which can be sold to conventional refineries for further upgrading. A carbon black is also produced which has the potential of being upgraded to higher value carbon black and activated carbon products. The Reviewers believe that extensive development work will be needed to secure these higher value markets. Husky states that their H-Rubber technology, a form of pyrolysis process operated under hydrogen pressure, will produce a superior carbon black product. This process has been demonstrated in small scale equipment but will need large scale continuous testing to confirm product yields and qualities.

A brief description of each project is provided below.

The Worthing Industries Inc. Proposal

This company proposes to establish a small plant at Olds, Alberta, in association with the Olds College. The simplified flow sheet of the process is shown in Appendix C and is similar to the Enerwaste process in that it yields gas, hydrocarbon vapours, oil, carbon and metal fragments. Instead of using the cross-conveyer system to drive the solids through the pyrolyser as Enerwaste proposes, Worthing establishes a bed of char in the pyrolyser. The pilot plant developed by Worthing is mounted on a trailer and is portable. It is considered capable of handling 310,000 tires per year. Capital cost of the unit was indicated to be $500,000. Products listed show that the feedstock is converted to: oil 40%, carbon 32%, gas 18%, and steel 10%. Compared with the product mix indicated by Enerwaste, Worthing would produce 20% less oil of a heavier grade, the same proportion of carbon and a greater gas fraction (18 versus 10%), suggesting that the Conrad Industries processing conditions proposed by Enerwaste are not as harsh as those used by Worthing.

Worthing does not remove traces of water before processing the shredded feedstock through the pyrolyser. If an emulsion of water in the oil is produced, it would be passed on to an upgrader at a reduced price. On the other hand, Enerwaste plans to dry its feedstock to avoid the production of emulsions.

The Enerwaste International Proposal

According to this proposal, a plant would be built at Camrose, Alberta. The technology to be used would be modelled after the Conrad Industries Inc. pyrolysis plant at Centralia, W. This technology has been developed in conjunction with Cleaner Products of Portland, Oregon. In this process, the shredded rubber is fed by means of an auger into a pipe running horizontally. (See the flow system diagram in Appendix C.) A drive shaft on which there are paddles drives the material being pyrolysed slowly through the pipe. The pipe is heated externally by gas heaters, the gas being part of the by-product gas (about 10 - 15% of it) from the process. Pyrolysis occurs producing gas, vapours, oil, carbon and metal fragments from the tire mesh and bead. When the pyrolysed material reaches the end of the first horizontal pipe, it drops into a second pipe where it is further pyrolysed, releasing gas as it is propelled through the pipe. The pyrolysed solids remaining drop into a third pipe which is cooled. The solids, carbon and metal fragments are passed into a separation system where the metal fragments are magnetically separated with some char. The carbon is passed through sieves to provide various size fractions ready for upgrading by acid washing or activation with steam.

Conrad has operated with various feedstocks indicating that the process could be applied in the pyrolysis of several waste materials to produce gas, vapour, oil and carbon. Waste materials such as polyethylene, polypropylene, polyester, wood, paper, municipal solid waste and hazardous wastes have been processed. The versatility of this process is one of its main advantages along with the fact that products such as gas, oil and carbon can be produced for sale. These products may be used again for various purposes rather than being completely consumed and forming carbon dioxide and water. This constitutes a form of "recycling" and "reuse." The process is self-sufficient in terms of energy.

Pyrolysis is not as far advanced in North America as is conversion of tires by means of cement kilns. There are reports, however, that pyrolysis is used extensively in Japan and Korea to consume wastes and to produce energy for the generation of steam and power.

In its proposed operations, Enerwaste International would shred tires at the various collection sites so as to be able to carry larger loads to the plant. At the plant, the shredded material would be shredded further, adding additional costs to the operation.

To obtain the highest prices on the carbon product, Enerwaste would employ acid leaching or steam activation to upgrade the carbon. Such operations would require the assistance of technically-trained staff who are knowledgeable in such procedures. The mass of the products produced would be relatively low so shipping these products to, for example, the Pacific Rim countries may be feasible.

The Husky Oil - CANA Proposal

Husky Oil - CANA proposed using the H-Rubber process (see chart in Appendix 3) which utilizes hydrogen to produce higher quality products which can be sold for a higher return.

Prior to shredding and "chipping" (¼") the tires, the tires are washed to remove dirt and soil. The product is then dried before it is added to the dissolving oil. After the pretreatment, the rubber is treated with hydrogen at 1000 psig and 750°F for a period in a backmixed reactor. The reaction system is designed to handle 100 tons per day (3.6 million tires per year). This quantity is significantly larger than would be required by any one of the other five proponents under review. All of the available tires from Alberta and some from Saskatchewan would be required to operate this plant. A threshold of 2.5 million per year would be required for the operation to be economically viable according to Husky's representatives. The company would try to procure waste tires from Saskatchewan if a sufficient quantity were not available in Alberta.

The Inland Cement Limited Proposal

The process (see Chart in Appendix C) is essentially the same as that of Lafarge Canada Inc. and also is based on the use of whole tires. The plant at full capacity would run 330 days per year. Based on sales projections and supplying product to Saskatchewan and Manitoba, it is estimated that the plant would operate 285-300 days per year. The upper processing limit based on the maximum test burn feed rate is between 800,000 and 840,000 tires per year.

The company has set a lower limit of 400,000 tires per year for the installation of the necessary capital equipment and staffing to be economically feasible at zero profit. This lower limit depends on fluctuations in gas prices and the actual recovery of energy from tires based on operating experience. Energy substitution from tires during the test burn was varied from 10-18%. Reasons given governing the percentage substitution were:

(i) kiln back end temperature;
(ii) kiln back end oxygen;
(iii) encrustations;
(iv) mechanical handling; and
(v) past experience with the Preheater Kiln.

Emission data on five other cement plants showing comparisons between operations with and without the addition of used tires were provided.

The Lafarge Canada Inc.Proposal

This company's revised process involves the automated addition of whole tires downstream from the precalciner into the kiln. The estimated cost of the system to inject single tires has been given as $1.8 million. The product revenue for the tire derived fuel has a value of approximately $0.43 per tire, based on gas at $1.50/GJ. There would be no solids discharge from the process because the solids from conversion of the tire materials become incorporated in the cement product.

With respect to air emissions, Lafarge states "Air emissions attributable to using TDF displace those of the alternate fuel that is cut back and, therefore, do not represent an additional emission load to the Alberta environment." The company has indicated that prior to installation of the tire addition process

at Exshaw, a comprehensive test for stack emissions would be required. Management has indicated that under no scenario which they have assessed, can they anticipate that the use of tire feedstock would adversely affect the company's ability to maintain the air emission requirements.

The revised Lafarge Canada Inc. proposal is conditional upon the following:

- Being able to obtain the necessary permits to operate a scrap tire processing site in Calgary and burn TDF at the Exshaw cement plant;
- Being able to obtain a minimum of 6,000 tonnes of scrap tires per year in each of the first 5 years of operation, or be compensated for any shortfall in scrap tire delivery;
- The Province passing suitable legislation to ban tires from landfill and prevent illegal dumping;
- The provision of an advanced disposal fee of about $2.50 per passenger and light truck tires or an equivalent amount for heavy truck tires.

One regular passenger tire was considered to be 8.2 kg while light truck tires and heavy truck tires were considered to be equivalent to 150% and 400% of this value, respectively.

A schematic flow diagram of the Lafarge Canada Inc.'s process is included in Appendix C.

The Pacific Integrated Waste Systems Proposal

This process is modelled after the Coeur d'Alene pilot plant operated by Energy Products of Idaho (EPI). Shredded waste tire is fed into a fluidized sand bed and incinerated to carbon dioxide and water. The metal from the steel mesh and tire bead, char and a mixture of lime and gypsum are removed. The flow system for the process is shown in Appendix C.

A comparison of the Pacific process with the kiln conversion processes of Lafarge Canada and Inland Cement is interesting in terms of the utilization of the energy in each case. Energy from the incineration of tires in the Pacific case is used to raise

steam from which, through a turbine/generator, electric power is produced. The low grade steam product is condensed and reused as boiler feed water. Losses of energy to the atmosphere occur during condensation of the steam. While the company does indicate that there is the possibility of using the waste steam to heat greenhouses, this proposal has not been formally developed and would depend on other entrepreneurs willing to become involved.

In the Lafarge Canada and Inland Cement operations, the energy from conversion of the tires would directly displace energy which would otherwise come from combustion of the equivalent amount, in terms of energy, of natural gas. Losses should be approximately the same as when natural gas is burned.

There have been dramatic reductions in the use of energy in the production of cement in recent years because of the introduction of the precalciner which has improved the efficiency of cement kilns markedly. The difference in energy utilization, therefore, stands out as one difference between the cement kiln and the power generation process of Pacific.

A second difference is in the capital which is required to put each operation into effect. As shown in Chart 4-1, on Comparison of Processes, the Phase II estimated capital required by Lafarge and Inland are $1.8 and $1.5 million, respectively, while the Pacific plant is estimated at $17.5 million.

The Lafarge and Inland capital requirements would be paid out in five years or less while the Pacific operation would require 20 years to pay out. This bears out the statement made in the "Scrap Tires News" Vol. 5, No. 123, December 1991 which states,

> "No green field plant, pyrolysis or otherwise, can compete with an already capitalized facility. So cement plants, for instance, in which direct burning of tires is just a materials handling problem, are to be avoided geographically." (Editorial note: this means avoided by non-cement plant project proponents)

During the above meetings, the opinion was expressed that some of the waste tires find their way into export markets to countries where they can be used as fuel or for other purposes without

concern for the environment. This led to the following questions? What has happened to the approximately 1.5 million waste tires produced per year for the past 10 to 20 years? Are they in landfills, are they scattered around the country, or have some been exported? Who will pay for processing tires in existence before the disposal fee is introduced? Does the government have sufficient funds in the proposed tipping fee to allow for these tires to be re-introduced into the system so that they can be "recovered" in some way?

CHART 4-1 - COMPARISON OF PROCESSES

ACTIVITY	WORTHING	ENERWASTE	HUSKY	INLAND	LAFARGE	PACIFIC
PROCESS	PYROLYSIS	PYROLYSIS	PYROLYSIS-HYDROGENATION	CEMENT PLANT FUEL	CEMENT PLANT FUEL	ELECTRIC POWER GENERATION
NO OF TIRES/YEAR	310K, EXISTING PILOT PLANT ONLY	DESIGN- 2.0M; REQUESTED- 1.5M	DESIGN- 3.3M; REQUESTED- 2.5M	0.66 M MAXIMUM- 0.84 M (2 TIRES/MIN, 300 DAYS)	1.0M, COULD GO TO 2.0M IN KILN #5 (0.6M MINIMUM)	1.5 M, SMALLEST REASONABLE COMMERCIAL SCALE
COLLECTION AND STORAGE METHOD	CALGARY AREA ONLY, USING DUMPSTERS	TRUCKS TO DESIGNATED REGIONAL TRANSFER DEPOTS (LAND FILL SITES); TIRES ROUGH SHREDDED WITH MOBILE SHREDDERS	DEPOTS AT HUSKY STATIONS AND RETAIL OUTLETS- 100 TIRE BINS; TRANSFER STATIONS AT EDMONTON AND CALGARY	COLLECTED BY PHASE 1 OPERATOR; 90K CAN BE STORED ON INLAND'S PROPERTY	50% FROM SHEPHARD LAND FILL SITE; BALANCE FROM DESIGNATED PICK-UP SITES	STORAGE BINS AT LANDFILL SITES AND AT TIRE DEALERS
TRANSPORTATION	DRY TRUCK VANS	4 TRACTOR-TRAILERS PER DAY; OUT-OF-PROVINCE TIRES BY TRAIN; RING ROAD ACCESS	DUMPSTER TRUCKS TO TRANSFER STATIONS; 10 1200 TIRE TRAILERS TO PROCESSING PLANT	"ENTREPRENEURIAL" TRUCKING TO EDMONTON PLANT, INVOLVING "TIPPING" FEE	COMBINATION OF TRUCKS (COMPACTOR CAPABILITY, SELF-UNLOADING)	BINS TRUCKED TO TROCHU, 5 TRUCKS PER DAY
STORAGE AT PROCESSING SITE	LINED AREA FOR STORAGE, SHREDDED TIRES IN CONICAL OUTDOOR PILE; ONE WEEKS SUPPLY WHOLE TIRES	2 YEARS SUPPLY SHREDDED TIRES, TO GENERATE EARLY CASH FLOW	CHIPPED TO 1/4 INCH; 30 DAY STORAGE IN NITROGEN-BLANKETED SILOS	2 DAY STORAGE OF WHOLE TIRES (6000)	SHOULD BE NEGLIGIBLE SUPPLY OF WHOLE TIRES IN REVISED PROPOSAL	4 DAYS WHOLE TIRE STORED INSIDE
PROCESSING LOCATION	OLDS	CAMROSE LANDFILL SITE	LLOYDMINSTER	EDMONTON	EXSHAW	TROCHU
PRETREATMENT APPROACH AT PROCESSING LOCATION	SHREDDED AND GRANULATED; STEEL REMOVED. NO WASHING	SHREDDED AND DRIED; TIRES NOT PREWASHED	WASHED AND CHIPPED; STEEL AND FIBRES REMOVED	WILL REQUIRE CLEAN TIRES; MODEST AMOUNT OF DUST OK.	NONE AT EXSHAW (WHOLE TIRE INJECTION)	SHREDDED TO 2", NO CLEANING OF TIRES OR REMOVAL OF STEEL
PROCESSING TECHNOLOGY	ENTRAINED GAS PYROLYSIS (NO SAND BED); CHAR PROVIDES "BED" MATERIAL; HAVE RELEASE FROM U OF WATERLOO LICENSE	50 TON PER DAY PYROLYSIS PLANT- TWO HEATED HORIZONTAL RETORTS; KLEEN AIR PYROLYSIS SYSTEM (STEEL REMOVED AFTER PYROLYSIS)	CHIPS DISSOLVED IN GAS OIL, PROCESSED IN REACTOR (BACK-MIXED) AT 750^{O} F AND 1000 PSIG; NO CATALYST	PROVIDES FUEL IN CEMENT PLANT KILN	PROVIDES FUEL IN CEMENT PLANT KILN	FLUIDIZED SAND BED COMBUSTION

	WORTHING	ENERWASTE	HUSKY	INLAND	LAFARGE	PACIFIC
LEVEL OF DEMONSTRATION	MOBILE PILOT PLANT, 8 HOURS LONGEST RUN	25 TONS PER DAY, KLEEN AIR PLANT IN WASHINGTON; 6 YEARS INTERMITTENT OPERATION	50 LBS PER DAY BENCH UNIT; DEMO RUN PLANNED IN 3-4 TPD PDU.	25 DAY TEST RUN; SHREDDED TIRE OPERATION IN BC AND CALIFORNIA; WHOLE TIRE TEST IN BELGIUM	TESTS IN QUEBEC AND KANSAS; EXTENSIVE COMMERCIAL OPERATION IN USA	MODESTO, CALIF., 14.5 MW (USES A TRAVELLING GRATE); FLUID BED PLANTS EXIST USING OTHER WASTE FEEDS
PRODUCTS, TYPE AND VALUE	OIL 40%, 85% % FUEL OIL CARBON- 32%, 5c/LB GAS-18%- USED IN PROCESS STEEL-10%, 2c/LB	OIL 50%, $21.67/BBL CARBON-32%, 25c/LB GAS-10% STEEL-7%, 5c/LB	OIL 53% $20/BBL CARBON- 40%, 16 CENTS/LB GAS- 4%, STEEL- 9%, 3-6c/LB	DISPLACED NATURAL GAS ($1.65/GJ) AND IRON	DISPLACED NATURAL GAS ($1.50/GJ) AND IRON	POWER- 2.75 MW STEEL- $.03/ PTE
CAPITAL COST	PHASE 2- $0.700M	PHASE 1- $2.0M PHASE 2- $8.5M TOTAL- $10.5M	PHASE 1- $5.4M PHASE 2- $25.5M TOTAL- $30.9M	PHASE 2- $1.5M	PHASE 1 - NIL PHASE 2 - $1.8M	PHASE 2- $17.5M
OPERATING COST	PHASE 1- $0.90/PTE; PHASE 2- $2.82/PTE	PHASE 1&2- $2.85/PTE	PHASE 1- $2.00/PTE PHASE 2- $1.88/PTE TOTAL- $3.88/PTE	$540K $0.82/PTE	PHASE 1 - $1.50/PTE PHASE 2 - $0.34/PTE TOTAL - $1.84/PTE	$1.8M PER YEAR $1.20 /PTE 88% SERVICE FACTOR
PRODUCT REVENUE	$0.68/PTE	$2.28M (3RD YEAR); $1.52/PTE	$2.52/PTE	$297K/YEAR DISPLACED FUEL- $0.45/PTE $33K/YEAR DISPLACED IRON- $0.05/PTE TOTAL- $0.50/PTE	$240K/YEAR IN DISPLACED FUEL; $0.39/PTE	$1.0M/YEAR $0.67/PTE
TIRE PROCESSING FEE ($ PER PTE)	$3.50	$3.50	$2.00- $3.00, DEPENDING ON TIMING OF AVAILABILITY OF FUNDS	PHASE 2- $2.35 PHASE 1- TIPPING FEE	PHASE 1- $1.50 PHASE 2 -$1.00 TOTAL - $2.50	$2.89
AIR EFFLUENTS	SO_2 FROM BURNING GAS CONTAINING SULPHUR COMPOUNDS	SO_2 FROM BURNING GAS CONTAINING SULPHUR COMPOUNDS	0.1 LB SO_x/PTE 0.01 LB NO_x/PTE	RESULTS OF INDUSTRY TESTS SUMMARIZED IN SECTION 6	RESULTS OF INDUSTRY TESTS SUMMARIZED IN SECTION 6	CLEAR EFFLUENT IF FILTERS USED

CHART 4-2 COMPARISON OF PROCESSES

PLANT LOCATION	TYPE OF PROCESS	PRODUCTS OF PROCESS
LAFARGE CANADA INC.(EXSHAW)	HIGH TEMPERATURE CONVERSION OF WHOLE TIRES	HC's* + O_2 → CO_2 + H_2O + HEAT CARBON + O_2 → CO_2 + HEAT STEEL (MESH AND BEAD) → CEMENT S + O_2 + CaO → $CaSO_4$ (CEMENT) Zn + O → ZnO → CEMENT
INLAND CEMENT LIMITED (EDMONTON)	HIGH TEMPERATURE CONVERSION OF WHOLE TIRES	SAME AS FOR LAFARGE
WORTHING INDUSTRIES LTD. (OLDS)	PYROLYSIS OF GRANULATED SHREDS OF TIRES	HC's -HEAT→ GAS + OIL + COKE → SALES + HEAT CARBON → CARBON → SALES + UPGRADING → SALES STEEL (MESH AND BEAD) → METAL RECYCLER S → CARBON AND CHAR PRODUCTS Zn → CARBON PRODUCTS
ENERWASTE INTERNATIONAL INC. (CAMROSE)	PYROLYSIS OF GRANULATED SHREDS OF TIRES	SAME AS FOR WORTHING INDUSTRIES LTD.
PACIFIC INTEGRATED WASTE SYSTEMS (TROCHU)	FLUID BED (SAND) INCINERATION OF GRANULATED SHREDS OF TIRES	HC's + O_2 → CO_2 + H_2O + HEAT CARBON + O_2 → CO_2 + H_2O + HEAT STEEL (MESH AND BEAD) → METAL RECYCLER S + O_2 (AIR) + $CACO_3$ (HEAT) → $CaSO_4$ + CO_2 Zn + O → ZnO (ASH)
HUSKY OIL/CANA (LLOYDMINSTER)	NON-CATALYTIC HYDROGENATION OF CHIPPED SHREDS OF TIRES IN OIL AT ELEVATED TEMPERATURE AND PRESSURE	HC's + H_2 → SATURATED HC's → OIL AND GAS → REFINERY → OIL & GAS PRODUCTS CARBON → CARBON (HIGHER QUALITY) STEEL (MESH & BEAD) → METAL RECYCLER S + H_2 + HC → H_2S → HCS → REFINERY ZnS → Zn (ASH) + CARBON (SULPHUR)

* HC's - HYDROCARBONS IN RUBBER

5. COMPARISON OF ECONOMICS

PHASE 1 COSTS

The Proponents who included Phase 1 in their proposal identified the following financial assistance requirements for this phase:

Lafarge	-	$1.50 per tire (Southern Alberta)
Worthing	-	$0.90 per tire (Calgary area)
Enerwaste	-	$1.44 per tire (all of Alberta)
Husky	-	$2.00 per tire (all of Alberta)

The Reviewers have been informed that U.S. trucking costs are $0.75 per kilometre (both ways) for trucks carrying 1,000 tires. This would result in trucking charge of about $0.37 per tire between Edmonton and Lloydminster and $0.79 per tire between Calgary and Lloydminster, which largely explains the difference in the above figures. An independent check on Canadian costs suggested the cost between Edmonton and Calgary would be in the order of $0.50 per tire, with the possibility of reducing this with back-hauls and larger trucks.

These data show the advantage in having more than one Phase 2 operation in the Province.

SHREDDING COSTS

The Reviewers obtained information on shredding costs from a variety of sources, which indicates that costs are highly dependent on the fineness of the shreds, as noted below:

2" by 2"	-	$0.25 - $0.50 per tire
1/2"x 1/2"	-	$0.75 - $1.00 per tire
Granules	-	$1.00 - $1.50 per tire

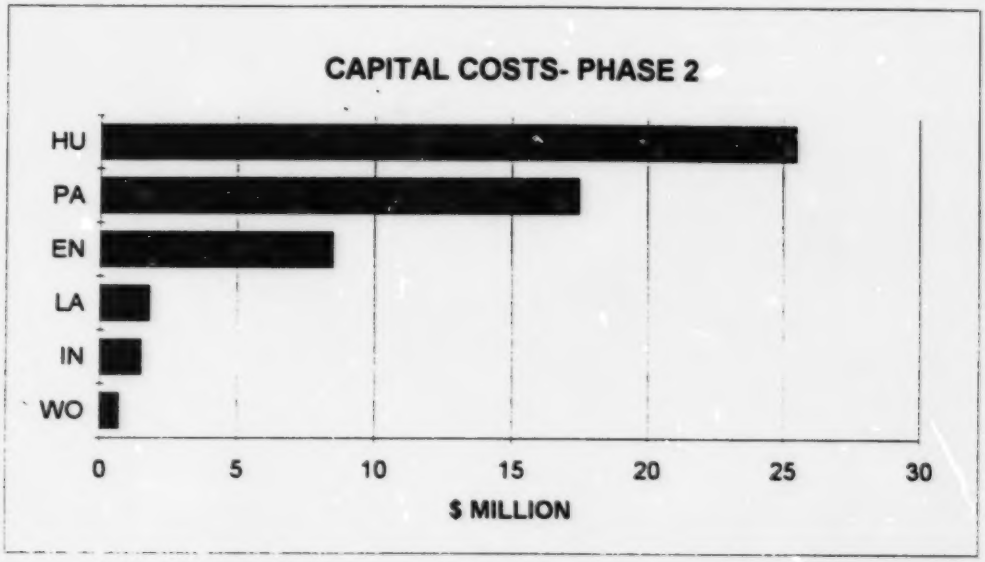
This illustrates the advantage in avoiding or minimizing the need for tire shredding.

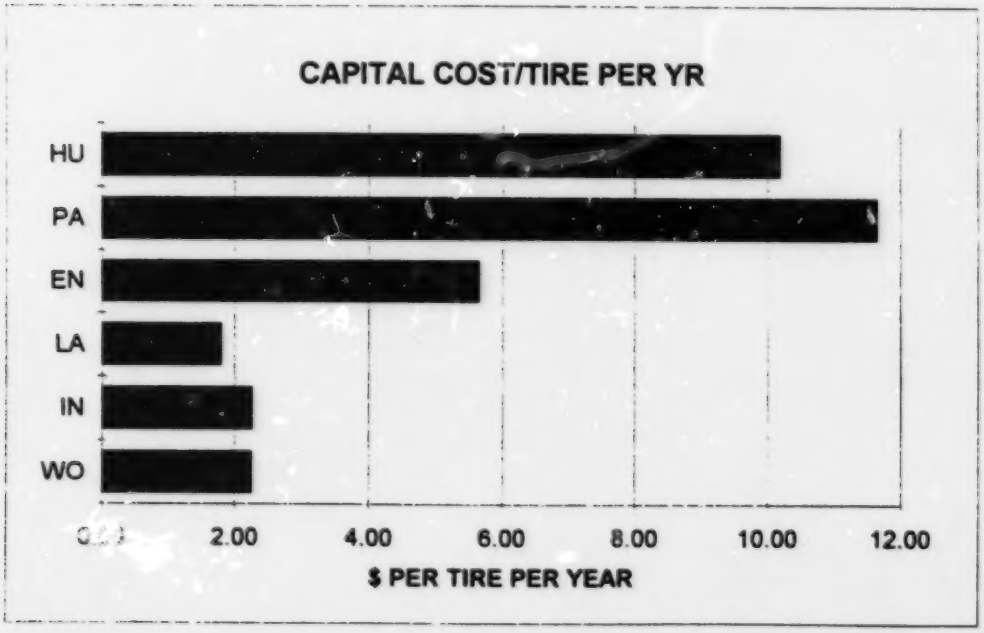
CAPITAL COSTS- PHASE 2

Chart 5-1 compares the initial capital costs for Phase 2 of the six projects, as identified by the Proponents.

CHART 5-1

COMPANY	PLOTTING CODE	CAPITAL COST PHASE 2- $M	TIRES/YEAR MILLIONS	CAPITAL COST PER TIRE/YEAR
WORTHING	WO	0.7	0.31	2.26
INLAND	IN	1.5	0.66	2.27
LAFARGE	LA	1.8	1.00	1.80
ENERWASTE	EN	8.5	1.50	5.67
PACIFIC	PA	17.5	1.50	11.67
HUSKY	HU	25.5	2.50	10.20





Since the capacities of each project are different, the capital costs are expressed on a tire per year basis in the lower figure of the chart. The Husky and Pacific Integrated projects have the highest capital costs, in the order of $10 per tire per year. Enerwaste has an intermediate value of slightly under $6, and the two cement plants and Worthing are in the $2 range.

The Proponents propose to provide the initial capital by one or more of the following methods:

a) by the company itself
b) from debt sources (eg: banks)
c) from tire fee revenue accumulated prior to Phase 2 start-up

PROJECT ECONOMICS

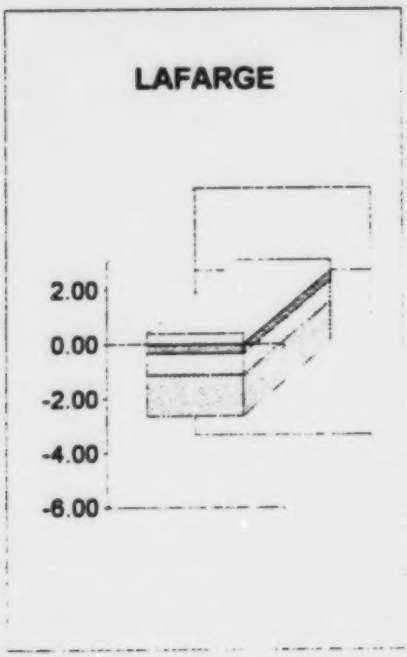
To permit a comparison of the viability of each project, the Reviewers have carried out an economic assessment, treating all capital in the same fashion.

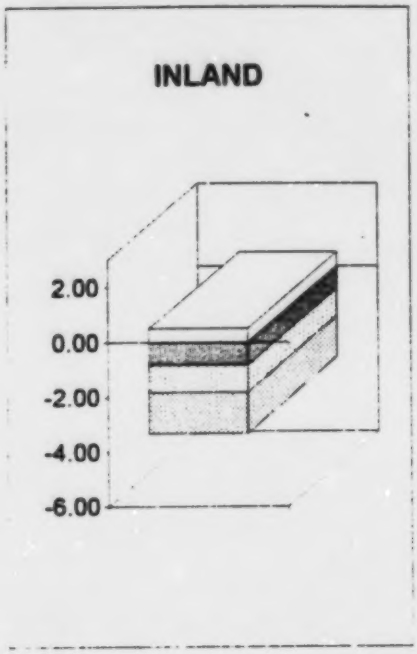
Since the cement plants already exist, the additional capital needed to feed used tires has been depreciated over three years, generally consistent with the approach used by the cement companies themselves. The Pacific, Enerwaste, and Husky projects have been depreciated over the expected life of the plants, 20 years. The Reviewers do not believe that the Worthing pilot plant could operate over long periods of time without the addition of significant capital, and a three year depreciation was therefore applied for this project. Although at least one Proponent has used a 20% rate of return for their investment, a real rate of return of 15% (after inflation) has been used in this report to determine a per tire capital charge, constant over the life of the project. No inflation has been included for revenue or operating costs.

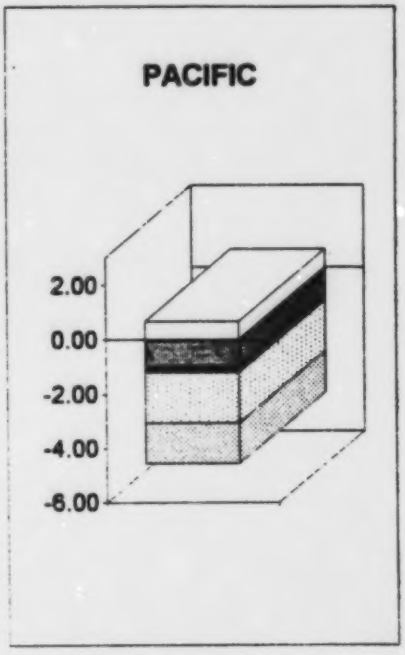
The economics for each project are illustrated in Chart 5-2, incorporating the annual product revenues and operating costs provided by the Proponents. The capital charges have been calculated by the Reviewers using the assumptions noted above. It should be stressed that the capital charges are on a total project basis, and are not equivalent to the capital charges that would apply to that part of the capital provided by the Proponents. The Proponents would presumably request a more rapid pay-back of capital than used in this review, for example by using a straight line depreciation.

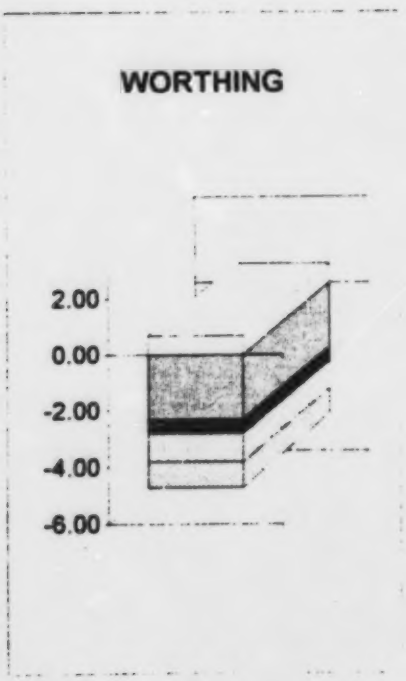
CHART 5-2

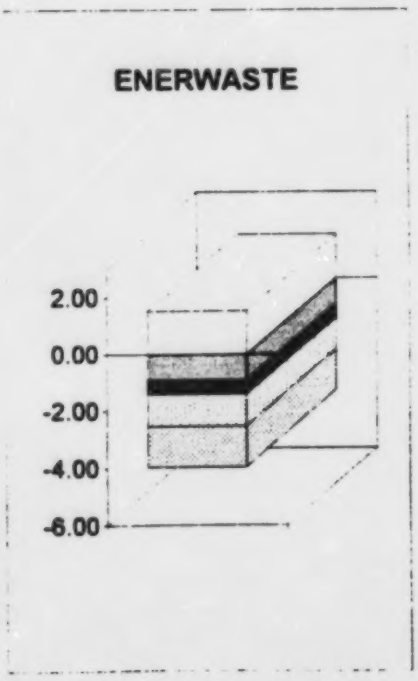
	LAFARGE	INLAND	PACIFIC	WORTHING	ENERWASTE	HUSKY
product revenue	0.39	0.50	0.67	0.68	1.52	2.52
operating costs	-0.34	-0.82	-0.95	-2.32	-0.91	-1.13
shredding	0.00	0.00	-0.25	-0.50	-0.50	-0.75
capital charges	-0.79	-0.99	-1.86	-0.99	-1.12	-1.97
collection and transp.	-1.50	-1.50	-1.50	-0.90	-1.44	-2.00
revenue - all costs	-2.24	-2.81	-3.89	-4.03	-2.45	-3.33

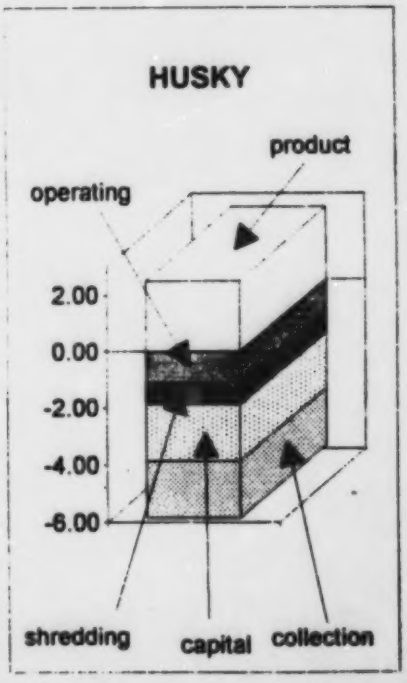












Lafarge

Lafarge has indicated that the initial capital required will be $1.8 million dollars, equivalent to $1.8 per tire per year. This is equivalent to a capital charge of $0.79 per tire. The upper left figure in Chart 5-2 shows the revenue and expenditures for the first three years. After three years, the capital charge should disappear, unless additional capital is required for continued operations. The tire fee required for revenues to equal expenditures is $2.24 for Phases 1 and 2, and $0.74 for Phase 2 alone. Lafarge have requested a tire fee of $1.50 for Phase 1 and $1.00 for Phase 2. The additional fee of $0.26 for Phase 2 requested by Lafarge is not unrealistic in view of the efforts required for permitting etc.

Inland

Inland has indicated that the initial capital required for Phase 2 will be $1.5 million, equivalent to $2.27 per tire per year. This is equivalent to a capital charge of $0.99 per tire. The upper centre figure in Chart 5-2 shows the overall revenues and expenditures.

Although Inland does not wish to be involved in Phase 1, $1.50 has been added for Phase 1 to allow comparison among projects. This analysis shows that the appropriate tire fee to make revenues equal to expenditures is $2.81, of which $1.31 would be attributed to Phase 2. Inland requested a tire fee of $2.35, considerably higher than this figure. Inland base this higher figure on the risks involved in tire supply, in legal and permitting costs and various unanticipated events.

As in the case of Lafarge, the capital charge would disappear after capital pay-back in three years. Inland has indicated that it would be willing to consider lowering its requested tire fee from $2.35 to $1.44 at that time.

In comparing Lafarge and Inland, the lower tire feed rate for Inland is responsible for about $0.50 of the total difference of $1.35 in the requested Phase 2 tire fee. The balance is due to Inland's request for compensation for their perceived higher project risk.

Pacific Integrated

Pacific has indicated that the initial capital required for Phase 2 will be $17.5 million, equivalent to $11.67 per tire per year. This is equivalent to a capital charge of $1.86 per tire. The upper right figure in Chart 5-2 shows the overall revenues and expenditures. The Reviewers have attributed $0.25 of the total operating costs for rough shredding.

Although Pacific do not wish to be involved in Phase 1, $1.50 has been added for Phase 1 to allow comparison among projects. This analysis shows that the appropriate tire fee to make revenues equal to expenditures is $3.89, of which $2.39 would be attributed to Phase 2. Pacific has requested a tire fee of $2.89 for Phase 2.

Comparison with the Modesto power plant in California suggests that the Pacific Project is permitted to sell less than two-thirds of electrical power of which it is capable. If it were able to sell the same amount of electricity per tire as Modesto, the product revenue would increase by about $0.33, with a corresponding decrease in the required tire fee.

Worthing

Worthing has indicated that the initial capital required for Phase 2 will be $0.7 million, equivalent to $2.26 per tire per year. This is equivalent to a capital charge of $0.99 per tire. The lower left figure in Chart 5-2 shows the overall revenues and expenditures. The Reviewers have attributed $0.50 out of the total operating costs for shredding.

The tire fee required to make revenues equal to expenditures is $4.03 of which Worthing would attribute $0.90 to Phase 1. The reviewers do not believe the existing portable plant could operate beyond three years without substantial additional capital outlays. Worthing has requested a tire fee of $3.50. Worthing anticipates a small deficit, which they are prepared to absorb (in essence, accepting a lower return on their investment).

Enerwaste

Enerwaste has indicated that the initial capital required for Phases 1 and 2 will be $10.5 million, equivalent to $7.0 per tire

per year. This is equivalent to a capital charge of $1.12 per tire. The lower centre figure in Chart 5-2 shows the overall revenues and expenditures. The favourable revenue outlook is predicated on the sale of carbon black at the average price of $0.25 per pound, well above fuel value. The Reviewers have attributed $0.50 out of the total operating costs for shredding.

The appropriate tire fee to make revenues equal to expenditures is $2.45. Enerwaste has requested a tire fee of $3.50. Enerwaste has indicated that it wishes to secure access to early tire fee revenue by shredding a two year inventory of feedstock.

Husky

Husky has indicated that the initial capital required for Phase 1 and Phase 2 will be $30.9 million, equivalent to $12.36 per tire per year. This is equivalent to a capital charge of $1.97 per tire. The lower right figure in Chart 5-2 shows the overall revenues and expenditures. The Reviewers have attributed $0.75 out of the total operating costs for the fine shredding specified by Husky.

The tire fee required to make revenues equal to expenditures is $3.33, of which $2.00 is attributed to Phase 1 and $1.33 to Phase 2. The favourable outlook for Phase 2 is dependent on Husky being able to market the carbon black at a minimum of $0.16 per pound, well above fuel value.

Husky has provided two advance tire fee scenarios. In the first, a tire fee of $2.00 would be collected prior to plant start-up and made available to match capital draw-down. In the second, a tire fee of $3.00 would be held in trust until plant start-up and then advanced in its entirety. In the first case, Husky secures access to approximately half the cost of the plant during the three year pre-start-up period. In the second case, Husky is reimbursed for over 72% of the capital costs at start-up.

GENERAL COMMENT ON ECONOMICS

A further feature of the economics of these six projects is the impact that an interruption in tire supply would have. <u>For Husky, Pacific Integrated and Enerwaste, the loss of tire supply would be catastrophic, in that there would be no revenue to meet the</u>

ongoing capital depreciation and fixed operating costs. For the cement plants, loss of tire supply in the first three years would be serious, but the amount of capital at risk is relatively small. After the third year, the risk for the cement plants would be negligible since the switch to 100% natural gas fuel could be readily accommodated.

FINANCIAL ASSISTANCE REQUESTED

The financial assistance requested by each Proponent is summarized in Chart 5-3, and compared with the fee calculated by the Reviewers to make revenues equal to expenditures.

CHART 5-3 SUMMARY OF FINANCIAL ASSISTANCE

PHASE	PROJECT	ACCESS TO EARLY TIRE FEE CAPITAL REQUESTED BY THE PROPONENTS - $MILLION	ONGOING TIRE FEE REQUESTED BY THE PROPONENTS- $ PER TIRE	TIRE FEE CALCULATED BY REVIEWERS ON A TOTAL PROJECT BASIS- $ PER TIRE
PHASE 2 ONLY	LAFARGE	0	$1.00	$0.74 [1]
	INLAND	0	$2.35	$1.31 [1]
	PACIFIC	0	$2.89	$2.39
PHASE 1 & 2	LAFARGE	0	$2.50	$2.24 [1]
	WORTHING	0	$3.50	$4.03 [1]
	ENERWASTE	$10.5	$3.50	$2.45
	HUSKY	$15.0 - $22.5	$2.00 - $3.00	$3.33

[1] 3-year capital pay-back; all others at 20 years

Note with respect to the calculations of capital charges in this section of the report: The capital recovery factors, using discrete rate-of-return tables, end of year payments, and 15% interest were 0.43798 and 0.15976 for three year and twenty year pay-backs respectively.

6. COMPARISON OF ENVIRONMENTAL IMPACTS

In the opinion of the Reviewers, all six projects can be designed and operated to meet existing environmental regulations. The Reviewers inspected commercial cement and power plants in California which met all California regulations. A demonstration pyrolysis plant was inspected in the State of Washington, and the Reviewers are confident that satisfactory technology exists to control harmful emissions from the pyrolysis process and its products. Emission data are provided in this report which will assist in developing appropriate emission monitoring systems for any of the above processes.

COMPARISON OF THE SIX PROCESSES PROPOSED ON THE BASIS OF THEIR ENVIRONMENTAL IMPACTS

Data gathered during the course of the review process are summarized in Chart 6-1.

The Worthing pyrolysis process occurs in a closed system except for the combustion of the produced gas which heats the feed to the pyrolyser. Gases produced by pyrolysis along with recycled gas fluidize the char formed in the process and carry the product vapours and particulate carbon over to the recovery system.

Data are lacking on the volume of process gas which would be burned and the analysis of the effluent stack gas going to the atmosphere. While much of the sulphur and zinc in the tires is likely to be present in the carbon black and oil products from the pyrolysis, some of it will be present in the gas which is burned and would cause formation of sulphur dioxide and zinc oxide which would be emitted. The extent of each of these emissions would need to be determined if this project were to proceed.

At the Modesto Energy Facility in California, in which 18,000 tires are consumed per day to generate steam and electricity, the zinc oxide produced in the combustion of the tires is collected in the baghouse and can be sold. The sulphur in the tires is burned to produce sulphur dioxide which is recovered from the effluent gas stream by passage through a calcium hydroxide scrubbing tower to produce gypsum which is sold as a soil conditioner. Nitrogen oxides are maintained within the allowable

CHART 6-1 - COMPARISON OF THE SIX PROCESSES ON THE BASIS OF THEIR ENVIRONMENTAL IMPACTS

	Carbon Monoxide	Sulfur Dioxide	Hydrochloric Acid	Nitrogen Oxides (NO_x)	Lead	Cadmium	Mercury	Arsenic	Chromium	Poly Aromatic Hydrocarbons	Poly Chlorinated Biphenyls	Chlorobenzene	Chlorophenols	Particulates	Furans and Dioxins (Total)	EIMC	Comments
EXISTING CCME STANDARDS	57 mg/m³ 50 ppm	260 mg/m³ 100 ppm	75 mg/m³ 50 ppm	400 mg/m³ 210 ppm	50 ug/m³	100 ug/m³	200 ug/m³	1 ug/m³	10 ug/m³	5 ug/m³	1 ug/m³	1 ug/m³	1 ug/m³	20 mg/m³	0.1 ng/m³	-	
NORTHERN INDUSTRIES INC.	EMISSIONS SOMEWHAT GREATER THAN THOSE OF ENSEWASTE MUCH OF PRODUCED GAS BURNED. OTHERWISE A CLOSED SYSTEM.													?	·0·	?	
ENSEWASTE INTERNATIONAL INC.	SMALL EMISSIONS FROM BURNING - 15% OF THE PRODUCT GAS			.....			APPROACHING ZERO							?	·0·	?	"ZERO EMISSIONS" TO BE ACHIEVED AS WELL AS THEY MAY BE DEFINED.
HUBET OIL - CANA		0.096 lbs/PTE		0.006 lbs/PTE			LARGELY A CLOSED REACTION SYSTEM WITH MINIMAL EMISSIONS.							?		?	SO_2 EMISSION OF 0.32 t/d MAY BE TOO HIGH.
INLAND CEMENT LIMITED		1.1 PPM 0.033 lbs/PTE	·0·	457.4 ppm 9.22 lbs/PTE	50 ug/m³	20 ug/m³		<10 ug/m³	40 ug/m³					?	0.06 ng/m³	2.56 ng/m³	NO_x HIGH ON TEST. SHOULD BE LOWER ACCORDING TO OTHER TESTS.
LAFARGE CANADA INC.			·0·				EMISSIONS NO GREATER THAN FROM CEMENT PRODUCTION OPERATIONS							?		?	
PACIFIC INTEGRATED WASTE SYSTEMS	57 mg/m³ 50 ppm 0.0169 lbs/PTE	185 mg/m³ 70 ppm 0.070 lbs/PTE	- 25 ppm 0.0056 lbs/PTE	286 mg/m³ 150 ppm 0.0567 lbs/PTE	20 ug/m³	80 ug/m³	50 ug/m³	1 ug/m³	5 ug/m³	5 ug/m³	0.5 ug/m³	0.5 ug/m³	0.5 ug/m³	19 mg/m³ 0.0051 lbs/PTE	0.5 ng/m³	?	PROPOSED LIMITS SET BY PACIFIC INTEGRATED WASTE.

limit by using ammonia addition in the combustion zone if necessary. Techniques such as these may be needed to permit the Worthing process to meet environmental standards.

The Enerwaste process is modelled after the Conrad Industries pyrolysis process which has been in operation in the State of Washington, near Centralia, for several years. It too is largely a closed system. The Proponent writes that "stated stringent air emission standards shall be achieved by employing 'best available technology' to ensure a nondetectable level of air emissions." They state further that "design and operation of the facility ensures zero emissions will be achieved as best as zero emissions may be defined."

The pyrolysis unit operates on heat from combustion of 10 to 15 percent of the gas produced. Although the volume of effluent gas would be relatively small compared with the Worthing process operated at the same throughput, it may be necessary to scrub the stream to remove sulphur dioxide. Whether zinc oxide could be formed in small quantities which also might require removal is not known, and would require determination.

The "H-Rubber" plant proposed by Husky is also a largely closed system since it is operated under pressure. Their proposal does indicate the addition of 0.52 t/d of SO_2 and 0.044 t/d of NO_x to the atmosphere. While these quantities are small relative to the Provincial totals, the addition of this quantity of SO_2 to the air mass of a populated area may necessitate control measures.

Conversion of tires to energy and components of cement is an accepted commercial operation in many plants in Europe and the United States. Comparison of the emissions of cement plants without and with the addition of tires as a partial replacement of the fuel shows little if any difference (See Chart 6-2). In some cases nitrogen oxides (NO_x) emissions are lower when waste tires are used as part of the fuel. Sulphur from the tires forms sulphur dioxide in the combustion zone and then reacts with the lime, CaO, produced in the presence of air to give $CaSO_4$. This can result in very low SO_2 emissions. A test done at Inland Cement in Edmonton on July 31 and August 31, 1991 showed 1.1 ppmv when feeding tires.

Other analyses carried out during this plant test show the concentrations for cadmium and lead in the effluent gas to be less than or equal to the standards, respectively. The

CHART 6-2 COMPARISON OF EMISSIONS FROM CEMENT PLANTS WITH AND WITHOUT TIRE FEED

EMISSION SPECIES	INDUSTRY TESTS
SO_2	TEST #1- SAME TEST #2- SAME TEST #3- HIGHER TEST #4- HIGHER TEST #5- SAME TEST #7- SAME TEST #8- LOWER
NO_x	TEST #3- LOWER TEST #4- HIGHER TEST #5- HIGHER TEST #7- LOWER TEST #8- LOWER
PARTICULATES	TEST #1- SAME TEST #2- LOWER TEST #3- HIGHER TEST #4- HIGHER TEST #5- LOWER
VOLATILE ORGANICS	TEST #1- HIGHER
SEMI-VOLATILE ORGANICS	TEST #1- LOWER
TOTAL HYDROCARBONS	TEST #2- HIGHER TEST #3- HIGHER TEST #4- LOWER TEST #8- LOWER
DIOXINS	TEST #1- LOWER TEST #6- HIGHER TEST #8- HIGHER
FURANS	TEST #1- LOWER TEST #6- HIGHER TEST #7- HIGHER
CHLORIDES	TEST #2- LOWER
ZINC	TEST #1- LOWER TEST #5- LOWER TEST #6- SAME TEST #7- HIGHER TEST #8- HIGHER
CHROMIUM	TEST #1- LOWER TEST #5- HIGHER TEST #6- HIGHER TEST #7- HIGHER TEST #8- LOWER

Test #1- Florida Crushed Stone
Test #2- Ashgrove Cement
Test #3- Portland Cement Association Source
Test #4- Portland Cement Association Source
Test #5- Tibury Cement
Test #6- Tibury Cement
Test #7- RMG Lonestar, Davenport
Test #8- Southwestern Portland Cement, Victorville

concentration of chromium detected was 0.04 mg/m^3 which is higher than the 0.010 value given for the standard. Arsenic was found to be <0.01 mg/m^3 compared with a value of 0.001 for the standard. These values should be checked over a period of time.

The nitrogen oxides (NO_x) test done on the emissions from the Inland Cement plant on July 31, 1991 showed a concentration of 451.4 ppmv (wet). The CCME standard is 210 ppm showing that at the time the test was done the NO_x value was high. From discussions at the Calaveras Cement plant in California, it was learned that nitrogen oxides in the effluent stream are generally low compared with the California standard when tires are being fed to the kiln. On June 11, 1992 when the visit to the Calaveras plant took place, the NO_x values were varying between 100 and 200 ppm. The permit allowed the plant to operate at emission concentrations as high as 350 ppm.

The management group at the Lafarge cement plant at Exshaw indicated that they would expect little change in SO_2 or NO_x concentrations in the effluent from the kiln when comparing the operation of the kiln without and with tires being fed. In their opinion, the CO levels would be expected to be the same or slightly higher when tires were being fed as fuel. The Manager of Environmental Affairs for Lafarge, in a communication to the Reviewers, stated that "Under no scenario that we have assessed, do we anticipate that the use of TDF will adversely affect our ability to maintain our air emission compliance requirements."

The Pacific proposal states under the heading Project Concept that with respect to Air Quality Standards, the company's objective is "to exceed the Alberta standards and to operate the project to the Canadian Council of Ministers of Environment (CCME 1989) standards." The design of the plant proposed is similar to a pilot plant which has been operated at Coeur d'Alene by Energy Products of Idaho. The shredded tire would be combusted in a novel fluidized bed reactor equipped to allow removal of the steel mesh and tire bead through the grid during operation. The plant is equipped with a baghouse to collect dust from the effluent gas stream. Limestone will be injected into the fluidized sand bed to react with the sulphur from the tire shreds which is oxidized to sulphur dioxide. If necessary, ammonia would be added above the combustion zone to react with the NO_x to reduce it to meet the standard. From an environmental standpoint having to handle 0.192 tonnes of lime/ash per tonne of tires may create problems in terms of a landfill. The company hopes to be

able to sell this product to a cement plant or to farmers as a soil conditioner. The ash collected in the baghouse also could create a dust problem unless care is taken in moistening it to prevent it from being spread by the wind.

COMPARISON OF THE CARBON DIOXIDE EMISSIONS

Although carbon di.xide is not now a regulated emission, concern over the greenhouse effect is increasing. An estimate was therefor made of the carbon dioxide emissions from the six projects.

Calculations were made based on data provided in a brochure by Conrad Industries Inc., Centralia, W., entitled "Cleaner Pyrolysis Systems, A Technology That Recovers Both Energy and Materials From Waste." The relative amounts of CO_2 which would be emitted by conversion of a tire in each of the proposed systems were determined. Data were provided by Husky Oil for its proposal. The results in summary show the emissions per tire as follows:

		kg/tire
1.	Lafarge	28.0
2.	Inland	28.0
3.	Pacific	28.0
4.	Husky	7.57
5.	Worthing	0.85
6.	Enerwaste	0.85

Products from the Husky, Worthing and Enerwaste processes would be refined to produce fuels and carbon products which would be used in a wide variety of applications, each product delaying the emission of the CO_2 until the product is ultimately converted to carbon dioxide and water. At that time all of the processes would have yielded the same quantity of CO_2 per tire. The value of the delay in the emissions is that it would give a very minor reduction in the total emissions of CO_2 while other means are being developed to reduce the overall load of CO_2 emissions to meet the objectives which have been set for Canada for the year 2005.

The maximum number of tires which might be converted per year to energy is estimated to be 2.0 million.

Carbon dioxide production per year from this quantity of tires being converted would be 2,000,000 x 28 kg/tire = 56,000,000 kg or 56,000 metric tons.

According to "World Resources 1992-93, A Guide to the Global Environment" published by Oxford University Press, the emissions of CO_2 around the world for 1989 (the latest available figure), totalled 21,863 million metric tons from fossil fuel consumption and cement manufacture.

The possible emission of an additional 56,000 metric tons from ultimate conversion of 2.0 million tires per year represents less than 0.0002% of the total carbon dioxide emissions.

The emission of CO_2 in 1989 from industrial sources in Canada was 455,530,000 metric tons. The 56,000 metric tons from conversion of 2.0 million tires to CO_2 and water represents about 0.01% f the total.

These percentage reductions are so small that the differences between the processes based on a delay in CO_2 emissions are barely significant in the overall context.

APPENDIX A- NOTES FROM MEETINGS WITH PROPONENTS

1. PACIFIC INTEGRATED WASTE SYSTEMS INC.

Date: June 1, 1992, 8:30 a.m.

Location: 407 2nd Street S.W., Calgary

Attendees: Hugh Ham
Bryan Scott
Mayor Al Gehring from the Town of Trochu
C.W. Bowman
E.L. Tollefson

Introduction

The meeting began with a verbal description by Mr. Ham of Pacific Integrated Waste's proposal for converting 1.5 million tires per year to steam, electricity, by-product steel mesh and a lime/ash solid product which can be used in concrete or cement manufacture. The representatives of Pacific Integrated Waste and the Town of Trochu agreed to answer questions which the reviewers had prepared.

Estimation of Tires to be Processed

Mr. Scott stated that initially they designed the plant to handle 1.25 million, 20-lb. tires but later raised this to 1.50 million to make the economics of the plant acceptable at a processing fee of $2.89 per tire. This quantity was considered to be somewhat more than half of the tires available in Alberta. These tires could be collected from an area within 100 miles of Trochu. Mr. Scott thought that there would be enough tires for one or more additional plants using other methods to reduce, reuse, and recycle this waste product. After searching for several years, the management of his company was convinced that incineration by the EPI fluidized bed process was good technology which would not be displaced for many years to come.

Demonstration Pilot Plant for the Fluid Bed Conversion Process

Bryan Scott indicated that a pilot plant operated by EPI at Coeur d'Alene, Idaho, had been demonstrated to members of the Trochu Town Council to show the impact of the product streams on the neighbourhood in which a plant is located. This demonstration served to develop substantial support for the proposal by the citizens of the Town of Trochu and the surrounding district.

Several Approaches to Conversion of Tires

In Mr. Scott's opinion, while there are several approaches to "recycling" tires, few of them can produce products for which there would be a market large enough to utilize all of the waste tires being produced in Alberta. Production of electricity, steam, wire mesh and a lime/ash product would be operated on a continuous basis. Tires from the surrounding area would be collected by firms equipped to do this job. Steam, wire mesh and lime/ash would be sold for use in greenhouses, in the steel industry and in concrete/cement production, respectively.

Collection of Waste Tires

Bins for collection of the tires would be installed at landfill sites, at major tire retailers and where there is a need at other waste collection centres. There would be regular collection of the tires and transfers to the proposed plant where they would be shredded prior to being processed. Only a four-day supply of the shredded product would be stored at the plant to reduce any possible fire hazard.

Shredding of Waste Tires

On being questioned about the shredding operation, Mr. Scott said that Pacific's design called for a heavy duty shredder which could handle several times the continuous hourly capacity of the plant in one, eight-hour shift. The resulting 2" x 2" product would be stored for use in the plant. It was his opinion that it was better to have a single heavy duty machine which could do the necessary shredding in a few hours per day. This would provide adequate time for maintenance. If noise were a problem, and this was not anticipated, it would be better to do the shredding during the daylight hours.

Video Presentation of Fluidized Bed Combustion as a Means of Converting Tires

A video was presented which described the fluidized sand bed combustion process and the generation of steam. The Reviewers asked if there was any concern that the wire mesh would accumulate and plug the bed. An illustration was provided of the base cone of the combustor, designed to facilitate removal of the mesh and tramp. Wire mesh was magnetically separated from the tramp. The sand was screened out and recycled to the bed. When asked if there was a commercial plant using tire shreds only as feed which could be visited, Mr. Scott replied that he would check on this matter but that the demonstration plant of EPI at Coeur d'Alene, Idaho, provided some of the evidence. He stated that the fact that EPI was willing to guarantee the operation should provide assurance of the proven nature of the process.

The Modesto Plant in California for Conversion of Waste

A plant at Modesto, California, about 70 miles from San Francisco, is operating and burning whole tires. It is designed with a travelling grate so it does not have the same combustion system. However, it is converting tires to electricity, steel, gypsum and ash without causing environmental problems. The plant produces 14.5 MW of electric power.

The Proposed Plant for Trochu

The proposed plant at Trochu would produce 2.75 MW of power as well as the power needed for shredding the incoming tires. It would produce steel equivalent in value to approximately $0.03 per tire. Capital cost of the plant would be $17.5 million.

The plant would not separate the mesh from the shreds prior to combustion because this is a very difficult operation which EPI has circumvented by developing a combustor capable of handling the mesh in the base of the combustor. The cost of operating the plant would be $1.8 million per year equivalent to $1.20 per tire. The company would employ 19 people and the plant would have an on-stream service factor of 88%. The value of the electricity produced would be $1.0 million per year which is equivalent to $0.67 per tire. A fee of $2.89 per tire would be

required to cover the cost of the capital needed to build and operate the plant over a 20-year period. This does not include the cost of 50 to 60 cents per tire for delivery of the tires to the plant.

Efforts by the Town of Trochu

Mayor Gehring commented that the Town of Trochu had drilled a new well which was capable of providing 140 I.G.P.M. The town has a 500,000 gallon storage reservoir so that there should be ample water to handle the 50 I.G.P.M. required for the production of steam, the necessary blow-down, and a reserve in case of fire.

It was pointed out that the concern expressed by the Drumheller Health Unit regarding the disposal of the lime/ash product had been settled and a permit had been granted. It is thought that the lime/ash product is more likely to be consumed in concrete or cement production so that there would be little need for the landfill.

Control of SO_2 and NO_x Emissions from the Proposed Plant

With respect to the possible emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), it was pointed out that EPI plants can meet the environmental regulations for air quality in California by adding powdered limestone into the fluidized bed (1500°F) and adding ammonia above the bed where the temperature is over 1800°F.

Use of Low Pressure Steam for Heating Greenhouses

The company had declined becoming involved in the construction and operation of greenhouses adjacent to the plant. This, however, remains a distinct possibility for entrepreneurial activity if suitable proposals from people with the necessary resources and know-how wish to take advantage of this opportunity.

General Comments

Pacific Integrated Waste presented a strong case for the reliable

conversion of 1.5 million tires per year to electric power, steel mesh, lime/ash and low grade steam using a fluidized bed combustor coupled to a steam and power generating facility. This quantity of tires consumed annually would leave about one million tires for conversion by other means. Combustion of the carbon and the volatile organic matter to produce steam would displace gas, oil, or coal which might otherwise be used to produce the same quantity of electric power and, therefore, would not increase emissions of carbon dioxide to the atmosphere. The emissions of other gases such as SO_2 and NO_x would be controlled within the guidelines set down by Alberta Environment.

The low grade steam could be used in greenhouses which might be built adjacent to the plant. The lime/ash product would find a ready market in the concrete/cement industry in the province.

No problems were foreseen in supplying the necessary water for raising steam, in handling the blow-down from the boiler or in controlling noise levels within the guidelines set by the ERCB for industrial plants operating in such an area.

The economics for this project are summarized in the following table, on a per tire basis. The capital costs, including return on investments, have been calculated as the value needed to make total revenues equal total expenditures. This approach is different than that used previously in Section 5.

Revenue	Requested Tire Processing Fee	Product Value	Total
	2.89	0.67	3.56
Expenditure	Operating Cost	Capital Costs	Total
	1.20	2.36	3.56

2. WORTHING INDUSTRIES INC.

Date: June 2, 1992, 8:30am - 12:00 noon

Location: 100 Discovery Place One
3553 -31st Street N.W.
Calgary

Attendees: Dr. Peter Fransham - Vice-President
Harvey Poon - C.E.O.
C.W. Bowman
E.L. Tollefson

The meeting consisted of a two hour discussion at Discovery Place One, followed by a visit to the pilot plant site at Ogden.

Number of Tires

The Proponent wishes to have the application modified to consist only of the existing plant, with a capacity of 310 k tires per year. After this plant is up and running, consideration would be given to the construction of a larger plant.

Collection, Storage and Transportation Method

The Proponent would use Roen Enterprises to handle the collection of tires in the general Calgary area. Dumpsters would be provided at selected sites, and Roen would collect and transport these to Olds, Alberta. The charge for this was expected to be $0.90 per P.T.E.

Storage at the Processing Site

One week's supply of whole tires would be stored. Although sand was proposed to fight fires, no equipment was specified to transfer the sand to the tires if they caught on fire. A liner will be provided to contain water run-off. The shredded tires would be stored outside in a conical pile. Drainage water would be collected and evaporated from ponds.

Processing Location

Olds is now favourably disposed towards the project. Contact can be made with Hugh Bodner, Olds Development Officer. The site to be used is in a noisy, dusty commercial area and noise and dust from the shredding operation are not expected to be a problem.

The shredders will be located outdoors.

Pre-treatment Approach

A smaller shredder has now been selected to match the size of the pilot unit. The Proponent is obtaining quotes from manufacturers, including Eidal Shredders. Zenith Engineering in Calgary has built a small tire shredder. Expensive shredders are expected to give a cleaner steel. Drying the tires prior to shredding is not planned. $15k has been provided to remove steel from the shredded tires. Sand and grit are not removed from tires prior to pyrolysis. The tires are put in a granular form to provide the small particles and fast reactions required for high liquid yields.

Processing Technology and Level of Demonstration

One major change to the pyrolysis process is the elimination of the sand bed. The tire particles quickly pyrolyse, resulting in finely divided char which acts as the bed (known as entrained gas pyrolysis). There are no plans to continually draw off accumulated solids. A shut-down for maintenance is planned once per week. (It was noted by the Reviewers that 0.1% sand on the tires would be equivalent to 120 pounds of sand per week.) The Proponent has a release from his licensing agreement with the University of Waterloo. There has been no evidence of coke build-up in the reactor or downstream vessels, but the longest tire run was 8 hours. There was no inspection of downstream vessels.

Products and Values

It is expected that most of the water fed to the pyrolysis unit will be trapped in the product oil as an emulsion. A 15% deduction from the fuel oil price has been included to allow for this. No free water is expected in the product stream. It was agreed that the cost of upgrading a relatively small amount of product may make upgrading economically infeasible. A lighter oil fraction could be separated which would have a higher value than fuel oil. Carbon is contaminated with 10-15% metals, mainly zinc. TransAlta is expected to accept this as a coal substitute. The produced gas will be largely used as plant fuel, by recycling

it to the pyrolysis unit. A propane powered boiler will provide start-up and auxiliary heat as needed. Excess product gas will be flared.

Economics (A hand-out was provided, June 1, 1992)

The Proponents provided some economic data on a per tire basis for the following table, and the balance was supplied subsequent to the meeting.

Revenue	Requested Tire Processing Fee	Product Value	Total
	3.50	0.68	4.18
Expenditure	Operating Cost	Capital Costs	Total
	3.72	0.62	4.34

The Proponent calculated the capital costs as shown above, and recognized that their requested tire fee would result in a small deficit, which the company was prepared to absorb (in effect, accepting a smaller return on investment). A front-end processing payment (requested in the original proposal) is not required for the smaller plant.

Environment

The contaminants in the original tire feed are expected to appear largely in the products, which will be moved on to others who have the facilities to handle them. The Proponents will attempt to provide the distribution of sulphur in the various product streams, and estimate the SO_2 release in the flared gas from each tire pyrolysed. Approximately 69 grams of SO_2 would be produced from the gas combusted to provide heat for the process. It would be necessary to scrub the tail gas to remove this SO_2 to reduce it to an acceptable level. Solids accumulation (non carbon) are unknown. Water effluents are expected to be minimal.

The following sulphur data were also provided subsequent to the meeting.

Whole tires: Sulphur (wt.%)- 1.33%
Weight tire (g)- 9080
Weight sulphur (g)- 120.8

PER TIRE ANALYSIS	YIELD (%)	WEIGHT (g)	SULPHUR (%)	WEIGHT S (g)
PYROLYSIS OIL	45.00	4086	0.87	35.5
CARBON BLACK	35.00	3178	1.59	50.5
GAS (BY DIFFERENCE)	20.00	1816	1.91	34.7

Project Philosophy

Dr. Fransham noted that pyrolysis recycles part of the tire back to liquid products and usable energy (char). If pyrolysis were adapted for handling all organic-containing wastes, it would reduce the demand for depleting fossil fuel resources. This is a strong argument for the use of pyrolysis processes for handling wastes in general. It may or may not be the preferred route for a particular waste product, such as tires.

3. LAFARGE CANADA INC.

Date: June 2, 1993, 2:00 p.m.

Location: Exshaw Plant in Exshaw, Alberta

Attendees: Claude Bertrand, Director, Co-processing and Environment, Technical Services
Christopher Bart, New Business Development, Systech
H.L. Youngsblood, President
Mike Pawlicki, Manager of Environmental Affairs
C. Shekhar, Process Manager, Richmond Cement Plant
Bernie Bonneau, Vice-President, Operations
Jean D. Catillon, Plant Manager
C.W. Bowman
E.L. Tollefson

Introduction

Mr. Bonneau led the discussion by describing the operations which take place at the Exshaw plant. He pointed out that adding waste

tires to the feedstreams of the two kilns which they operate is not "incineration." The tires would be converted largely to heat energy, an input upon which their process is very dependent. The tires would also add a significant fraction of the iron required in preparing the cement mixture. Addition of tires to the feedstreams to the kilns would not create any additional emissions to the environment. The organic matter and the carbon in the tires would be completely consumed in the conversion process so that there would be no release of toxic organics or other volatile organic matter.

New Revised Proposal

Mr. Bonneau noted that since their proposal for the collection and processing of scrap tires was submitted in September 1991, their approach and the economics of the process have been greatly improved. These improvements stem from the fact that the company has determined that whole tires can be fed to the kilns without detrimental effects. This reduces the costs of the process because shredding is no longer required. As a result, energy and manpower requirements are reduced.

Operation of a Commercial Plant

A commercial cement plant at Redding, California, is now operating a fully automated tire feed system equipped with an automatic tire singulator. Tires are separated from a randomly packed feed hopper, one by one, and are fed into the kiln through two hydraulically-operated flap valves which form a locking system. The tires enter the kiln at the base of the precalciner without the loss of significant quantities of heat or process gases. No smoke or odours associated with the conversion of tires can be detected from the operation.

Efforts will be made to obtain a report from the U.S. Environmental Protection Agency which indicates that from an environmental standpoint, this is the "best way" to dispose of waste tires. The California Waste Management Board was said to favour the process also. Some 18 cement plants were reported to be operating using waste tires as part of the fuel requirements.

Tire Derived Fuel (TDF)

It was reported that to supply 10% of the fuel requirements of kiln #5, i.e. the kiln equipped with precalcination stages, one million tires per year would be required. Up to 30% of the fuel requirements from waste tires is manageable, but most plants burn approximately 20%. This level of tire derived fuel addition is well proven. At Exshaw, the cost of energy as part of the total operating cost was considered to be approximately 16%.

The managers were of the opinion that to make use of tire derived fuel worthwhile, they would want to be guaranteed a minimum of 6,000 tonnes per year of tires. To make the investment of approximately $1.0 million to install the automatic feed system profitable, it was stated that 9,000 tonnes or 990,000 tires per year were needed.

The company senses that the public and the government may wish to have the tires consumed in other ways, so that there is a usable end product, such as rubber mats. For this reason, a rapid pay out of the approximately $1.8 million total investment is desired, possibly within three years. The opinion was expressed that there should be enough tires available to supply more than one type of recovery operation.

Collecting Waste Tires

It was pointed out that for safety and aesthetic reasons, it was desirable to keep the stockpile of tires at the plant at low levels, e.g. 9,000 - 15,000 tires. Tires could be trucked from a central depot to the plant by a trucking firm on a regular, demand basis. These tires would have to be stored under conditions which adhered to the Provincial Fire Code. It was suggested that the Shepherd landfill site might be used as a collection depot. This could be readily guarded, and being fenced off, was a relatively safe storage area.

A rebate fee of $0.25 per tire was believed to be sufficient to encourage people to bring their waste tires to the depot. It was stated that about 30% of the tires would be resold by tire jockeys for retread use. If landfills were allowed to charge a dumping fee of $1.00 per tire, these tires would soon find their way into other channels. Montreal apparently has a system which offers $0.35 per tire, while tire jockeys offer $0.30 to $0.50 per tire.

Handling Off-Highway Tires

Questions were raised about handling the large off-highway tires which have very heavy beads. The automated feed equipment thus far developed would not accommodate such tires. These tires would, therefore, have to be separated and possibly sent to landfills. Consideration is being given to the development of tools to remove the bead and to cut the remainder of the tire in half, so that the two halves could be fitted together and thus occupy less space in a landfill. The possibility of reducing the size of these pieces of tire and shredding them so that they could be fed to a kiln has yet to be worked out. It is apparent that handling of these large tires is much more labour-intensive and that the fee to handle them would have to be higher.

Washing Tires Prior to Conversion in a Kiln

The question was raised as to whether it would be necessary to wash the tires prior to feeding them into a cement kiln for conversion. It was recognized that dirt on the tires would be very hard on shredder blades, but since the tires would not be shredded, this problem has disappeared. The presence of dirt in small quantities was considered to cause no problems since it is largely lime, alumina and silica which are components of cement.

Pyrolysis of Waste Tires

There was some discussion of pyrolysis as a means of disposing of tires. While this process produces a gas fraction, fuel oil, "carbon black" char and metal mesh, it was stated that there was an insufficient volume of the oil and the carbon black to support upgrading. Hence, the prices which could be recovered from these products would be relatively low. Much of the gaseous product would be consumed in the pyrolytic process. In view of these factors, the opinion was expressed that pyrolysis of tires is not financially feasible.

Pyrolysis requires that the waste tires be shredded. The cost of shredding to 2" x 2" pieces, would be about $0.50 per tire, while granulation of waste tire to about 0.62" x 0.62" would cost $1.00 per tire.

Emission of SO_2, NO_x and CO from the Kilns

Results of trial runs suggest that there would be little if any change in the concentration of SO_2 leaving the kiln. Since limestone is converted to lime in the kiln, the latter would be expected to react with any additional SO_2 from sulphur in the tires to form $CaSO_4$ in an oxidizing atmosphere. This would in effect trap the SO_2.

It was noted that most of the NO_x produced in the kiln is formed in the reducing end of the kiln. No significant change in NO_x levels are anticipated if waste tires are fed as fuel. In some tests, NO_x has been found to be lower when tires were fed. Carbon monoxide levels are expected to be the same or slightly higher when waste tires are used as fuel. This could, if necessary, be countered by adding more air to the kiln so that some CO would be converted to CO_2. Such action, however, may have a detrimental effect on the production of NO_x.

Development of the Tire Fee

There was considerable discussion of the method used to calculate the tire disposal fee. Christopher Bart of Systech agreed to provide input on this matter to Clem Bowman. A letter from Mr. Mike Pawlicki to Eric Tollefson and Clem Bowman dated June 5, 1992 indicated that the company's revised estimate of the disposal fee need would be about $2.50 per tire. Tires fed to a cement plant replaces fuel valued at $1.50/GJ.

The economics for this project are summarized in the following table, on a per tire basis. The capital costs have been calculated as the value needed to make total revenues equal total expenditures. This approach is different than that used previously in Section 5.

Revenue	Requested Tire Processing Fee	Product Value	Total
	2.50	0.39	2.89
Expenditure	Operating Cost	Capital Costs	Total
	1.84	1.05	2.89

General Observations

Lafarge Canada Inc. has the opinion that there is a very good fit between their needs for low cost fuel and the needs of the Province of Alberta to dispose of the millions of waste tires. Lafarge considers that conversion of these tires into energy and materials for cement production is a very satisfactory way to solve the problem. The process has been proven commercially and is considered to be environmentally satisfactory. This process offers a means of utilizing a considerable fraction of the waste tires available without creating environmental problems and without necessitating the expenditure of large amounts of capital. The process would provide jobs for those collecting and hauling tires, as well as for a small crew which would be responsible for feeding tires to the kiln.

4. ENERWASTE INTERNATIONAL INC.

Date: June 3, 1992, 8:30 a.m.

Location: 800, 333 - 5th Avenue S.W., Calgary

Attendees: Bruce Sinclair
Nelson Bump
Camrose Mayor Norman Mayer
Dennis Twomey
C.W. Bowman
E.L. Tollefson

Mr. Bump gave a presentation describing the Enerwaste project, noting several changes which have been made since the initial proposal was submitted. Emphasis was placed on the high employment provided (90), the commitment to a carbon upgrading line, the experience gained at the Centralia project, the ability to handle other waste materials and the advantages of pyrolysis over incineration. A video was shown of the Centralia operation. Following this presentation, discussion focussed on specific questions raised by the Reviewers.

Number of Tires

The requested number of tires is 1.5 million per year. The design capacity of the plant is 2.0 million tires per year.

Collection, Storage and Transportation

Transportation to Camrose would be by tractor-trailers (averaging 4 per day). The Camrose ring-road would provide easy plant access.

Storage at Processing Site

Final shredding would be carried out at Camrose. The need for 2 years' supply of shredded tire storage was discussed. Enerwaste admitted that the need for this was largely dictated by the requirement for early capital (from the tire processing fee) for construction of the processing plant. It was stated that this was of crucial importance to the bank. In response to the question about the fairness of receiving the entire processing fee when only the shredding operation had been completed, Enerwaste indicated that this was a negotiable item. There would be 5 working days of whole truck tire storage.

Pretreatment

A rotary drier is provided after the feed drum as part of the pyrolysis train. Dirt is not expected to be a problem and no washing of the tires is planned.

Processing Technology

The pyrolysis unit involves two horizontal "augers" feeding shredded tires. Heating occurs by the indirect contact of hot gases on the walls of the retort. Reamers are provided to prevent blockage at the feed end. There is no evidence of coke formation in the downstream vessels in the Conrad plant.

Products

Enerwaste indicated that they do not plan to upgrade the product oil, recognizing that the additional capital cost could not be justified. However, they are committed to a carbon upgrading line. They do not plan to sell the carbon as a fuel. They believe the worst case would be to sell it to a carbon distributor

at 13 to 15 cents U.S. per pound. Upgraded value would be 31 cents for basic carbon black. Enerwaste believes it can sell excess gas without further treatment. The drier prior to pyrolysis ensures that minimum water is emulsified in the product oil. They do not know if water is formed during pyrolysis. The moisture content in the carbon is in the 0.03 to 0.18% range.

Economics

The Reviewers outlined the standard revenue/expenditure chart they are using to compare projects. Enerwaste noted that the figures are highly dependent on the number of tires processed. Based on the requested 1.5 million per year figure,the following data were provided. The capital costs have been calculated as the value needed to make total revenues equal total expenditures. This approach is different than that used previously in Section 5.

Revenue	Requested Tire Processing Fee	Product Value	Total
	3.50	1.52	5.02
Expenditure	Operating Cost	Capital Costs	Total
	2.85	2.17	5.02

Environmental Issues

Enerwaste indicated there would be no waste water or solids leaving the plant.

The gas composition is (vol %)

H_2S	0.17
CO	2.10
N_2	14.17
CO_2	1.64

No figure was given for NO_x.

General Comments

Mayor Mayer stated that the project has the full support of the citizens of Camrose. He noted that the government's previous decisions have not solved the original problem - i.e. getting rid of all the waste tires. He noted that there were no financial obligations to the government in the Enerwaste proposal.

Enerwaste indicated they are having discussions with Dr. Peter Fransham concerning the use of his pyrolysis technology.

They stated that the Centralia plant has been operating continuously for 6 years.

5. INLAND CEMENT LIMITED

Date: June 4, 1992, 4:00 p.m.

Location: Edmonton Plant of Inland Cement
12640 - 156 Street
Edmonton, Alberta

Attendees: Vince Heron, Manager of Engineering
Dave Pickerell, Environmental Engineer
David Selleck, Regional Vice-President, Environmental Management
Keith Meagher, Process Superintendent
Bob Rymes, Plant Chemist
C.W. Bowman
E.L. Tollefson

Introduction

David Selleck presented an overview of the operations at the plant. He pointed out that the technology for utilizing rubber tires in cement kilns is now well established. The whole rubber tire can be employed as an alternate fuel for the cement kiln. The process would conserve a non-renewable natural resource, natural gas. It would improve the competitive position of the cement industry in Alberta. The life of landfills would be extended and it would offer an environmentally sound procedure for handling waste tires.

A 25-day tire test project conducted in August 1991 indicated

that the plant could consume tires at a rate ranging from 1,500 to 3,000 tires per day. With the installation of automated equipment for feeding the tires, the plant would consume 660,000 tires per year based on 220 operating days. It is likely that the plant output will increase in the future so that the number of tires which could be processed will probably increase.

Collection of Waste Tires

Inland Cement Limited did not become involved in Phase I of the waste tire disposal program. The company would depend on one or more trucking firms to deliver tires to a site west of the plant where up to 90,000 tires might be stored. Only a two-day supply of 6000 tires would be maintained on the plant site for insurance reasons.

Automated Tire Feed System

An automatic feed system would include a hopper to hold the tires being fed, a singulator which could feed single tires into a conveyor system up to the kiln injection point, a chute, an air lock system and items such as a front end loader and a television camera system with which the feed system would be monitored. The capital cost of such a system has been estimated at $1.5 million, while the operating costs would be $200,000 per year to provide for one additional person on each shift plus a relief operator and a supervisor. The company would request the equivalent of $2.35 per tire as assistance in conducting this service and would want the fee (Phase II) to remain in effect for five years.

It is expected that tires would be collected from the area in Alberta north of Red Deer if this program were to proceed.

Operation of a Commercial Plant

It was pointed out that the proposed process is well-proven. Inland Cement is a member of the CBR group of companies, one of which is the Calaveras cement plant at Redding, in northern California. This plant has been burning shredded tires at the rate of 14,000 tonnes per year (1.5 million tires) since 1986. This consumption rate represents 20% of the plant's energy requirements. The plant has met all state and county environmental guidelines. In August 1991, a system was installed

so that whole tires could be injected rather than shreds. This has eliminated the cost of shredding which was estimated to be $25.00 per tonne of tires.

It was learned that 18 to 20 cement plants in the United States are using waste tires as a fraction of their energy feed.

Tire Derived Fuel as a Source of Energy for Cement Kilns

It was stated that 15% to 18% of the total energy utilized by a cement kiln can be supplied by feeding waste tires. The temperature at the end of the kiln where injection occurs rises to 1200°C when the tires are added. Some encrustation may occur at the entrance to the kiln, so precautions need to be taken.

Tires take two to five minutes to burn in a kiln. The material added in the form of a tire has a residence time of 20 minutes in the kiln. The kiln at Inland is 58 m long and rotates at 3 RPM. The maximum flame temperature in the kiln is approximately 2300°C. Approximately 60% of the energy introduced into the process is added in the precalciner.

During the tire test burn there was no evidence of any smoke generation or of any visible discharge from the stack. Teams of observers were on hand to see whether there might have been any detrimental effects. Ten individuals interested in the performance of a cement kiln in consuming waste tires as part of the feed to the kiln were given tours of the plant during the test.

Effects of Processing Tires in a Kiln on the Product Gas Analysis

Addition of tires as feed to a kiln has been found to reduce NO_x by 50% from 800 to 400 ppm, approximately.

SO_2 values in the tail gas are found to be very low.

A discussion on the economics of waste tire processing at the Inland plant indicated revenues and expenditures would be as follows, on a per tire basis. The capital costs have been calculated as the value needed to make total revenues equal total expenditures. This approach is different than that used previously in Section 5.

Revenue	Requested Tire Processing Fee	Product Value	Total
	2.35	0.50	2.85
Expenditure	Operating Cost	Capital Costs	Total
	0.82	2.03	2.85

It was indicated that before Inland would commit $1.5 million in capital to install the automatic feed system, the company would have to be assured of a minimal supply of tires over a five-year period and would have to establish contracts with trucking firms to deliver the tires to the proposed site west of the plant.

According to Inland, the "facilities component" included $500,000 per year for a three-year pay back of the $1.5 million investment, $738,000 for pre-tax return on investment and $100,000 for the capital cost for financing the declining balance, giving a total of $1,338,000 as indicated on page 22 of Inland Cement Limited's proposal. This gave a tire fee of $2.35 over the five-year period.

General Observations

The management at Inland Cement Limited is anxious to proceed with the use of tires as a feedstock, provided a minimum supply of 660,000 tires per year can be guaranteed by the Province of Alberta. The management is confident that the conversion of tires in a cement kiln is environmentally as safe as is operation of the kiln when tires are not being fed to the kiln. While the process does not provide a by-product, it does provide energy and some material addition to the cement product. Management considers the process to be commercially proven.

6. HUSKY OIL LTD./CANA LIMITED

Date: June 9, 1992, 1:30 p.m.

Location: Carillon Room, Alberta Legislature Building

Attendees: Peter C. Quinn, President HRI Inc.
Geoffrey E. Dennis, Manager, Technical Services HRI Inc.
John D. Simpson, President CANA Limited
C.W. Bowman
E.L. Tollefson

The comparative spread sheet was used as a basic format for the discussions.

Plant Size

The plant was designed to handle 3.3 million tires per year on a full calendar basis. The expected number of stream days is 200 to 220, requiring 2.5 M tires per year. This is the smallest feasible commercial size. If Alberta could not supply this quantity of tires, Husky would be prepared to replace any deficiency from Saskatchewan.

Collection/Storage/Transportation

Husky would recommend establishing collection depots at facilities which are in the tire business, including those of competitors. They believe the consumer rebate should be at least $1 per tire, and also mentioned a top figure of $2 per tire. The Proponents expressed concern that the two projects previously selected by the government did not meet the RFP criteria of a comprehensive collection system from across the Province, the required environmental impact assessment, and Alberta content and financial capability requirements. Husky noted that CANA will be investing in the project, which will help ensure the integrity of tire supply.

Pretreatment

Tires would be chipped to 1/4" size (but not fully crumbed). The tires would be washed prior to chipping. It was noted by the

Reviewers that the expected dirt/soil discharge from the plant was equivalent to 1 lb. per tire (5%), much higher than figures quoted by other Proponents. Husky responded that they believe this to be a reliable figure based on their inspections of tire storage sites. They have given some consideration to freeze shredding, but admit the added capital is high. They would be prepared to supply a few tons per day of chips to other companies.

The steel and some of the fibres would be removed following chipping. The balance of the fibres either dissolve in the gas oil (polyester), or appear in the dried carbon (fibreglass and Kevlar) and would be removed by air elutriation.

Husky indicated it would nitrogen-blanket the storage silos if necessary to prevent fires.

Processing

Husky management do not call their process "pyrolysis", preferring its trade name of H-Rubber Processing. Test work to-date on tires has been in batch autoclaves or small continuous-flow bench units. Tests are planned in a 2000 cc bench unit to finalize process conditions. Although 1500 psig and 800°F were specified in the proposal, they believe that 1000 psig and 750°F are more likely conditions. Husky feels that the extensive test work on the H-Coal process provides confidence for their design parameters.

Although a catalyst improves the product oil quality, it does not lead to a better carbon product and therefore has been eliminated. The process involves a back-mixed reactor, not an ebullated bed. They believe the carbon can be sold for 20 cents a pound, equivalent to oil at $20/BBL. (The coal equivalent fuel value would be 5 cents/pound.)

The Reviewers noted that the hydrogen consumption quoted in the proposal was equivalent to 0.2 lb. per tire. Husky indicated this figure was based on oil upgrading technology and is probably five times too high. (Hydrogen consumption is expected to be 300 SCF/BBL, to saturate butadiene.) The oil portion of the tire dissolves in the gas oil used in the hydrogenation in 20 minutes.

The Reviewers asked for a comparison of oil/gas/carbon yields and values for H-Rubber processing, in comparison to straight

pyrolysis. Husky indicated the gas make was 5%, much lower than figures reported for pyrolysis. Husky stated that pyrolysis makes an inferior carbon black which is unsuitable for use in tires.

Environmental Aspects

The Reviewers had inferred from the proposal document that the project was based on a tire sulphur content of 0.5%, less than half the normally quoted figure. Husky agreed to clarify this point, and to provide a more complete sulphur balance. They also agreed to supply data on effluents on a per tire basis.

Husky noted that the process will not increase CO_2 emissions, since the oil will back out an equivalent volume of conventional crude. They agreed that the hydrogen plant will generate some additional CO_2. The carbon is not burned to CO_2 as occurs in incineration processes.

Economic Aspects

The Reviewers showed Husky the revenue/expenditure forecast prepared from data in the proposal, expressed on a per tire basis. Husky agreed to verify the data subsequent to the meeting. They noted that the economic figures would depend on the extent of access to tire fee funds in advance of plant start-up.

Husky noted it was their intention to have a 20-25% return on their portion of the capital investment, with any excess being returned to the tire fund.

Subsequent to the meeting, Husky provided the following revenue/expenditure forecast.

Revenue	Tire Processing Fee	Product Value	Total
	2.00	2.52	4.52
Expenditure	Operating Cost	Capital Costs	Total
	3.88	0.64	4.52

Also provided was a yield comparison with pyrolysis, shown in the following table.

Yields on Per Tire Basis[1]	H-Rubber	Pyrolysis
Liquid Yield	4.90 kg	3.65 kg
Gas Yield	0.40 kg	1.40 kg
Carbon Black Product Yield	3.05 kg	N/A
Carbon Char Yield	N/A	3.20 kg
Steel Yield	0.62 kg	0.62 kg
Fibre Yield	0.10 kg	0.10 kg
Less Chemical Hydrogen (manufactured on site)	-0.10 kg	N/A
Material Balance	8.97 kg	8.97 kg
SO_2 Emission[3]	0.47 kg	
CO_2 Emission[4]	7.60 kg	Data not Available[5]
S Recovery	0.02 kg	
Dirt and Debris Recovery	0.45 to 0.50 kg	

Notes:

1 1 tire = 8.25 kg "Rubber"
0.72 kg Fibre and Steel
8.97 kg Total

2 Reference: "Markets for Scrap Tires" #EPA/530 - SW - 90 - 074A October, 1991. Qualities of liquid and carbon products inferior to H-Rubber products

3 From H_2S in offgas, equivalent to 54% of total sulphur in feed rubber

4 CO_2 emissions are made up from:
(a) Power Generation: 2.4 kg
(b) Fuel for heater: 3.03 kg
(c) SMR Hydrogen Generation: 2.14 kg

5 Information on emissions and recovery of waste streams for pyrolysis was not available

APPENDIX B- SITE INSPECTIONS

1. MODESTO POWER PLANT

Date: June 10, 1992

Location: Modesto, California

Attendees: Douglas Tomison, Plant Manager
Bryan Scott, Pacific Integrated Waste
C.W. Bowman
E.L. Tollefson

General

The CMS Modesto Energy Company Inc. is fuelled by whole tires. The Plant Manager has been involved with the project since 1987 and is highly knowledgeable about all facets of the project, including economic, environmental, engineering and other technical matters. He noted that CMS has three plants burning whole tires in the U.S. These are the only energy plants at this time which are fed whole tires.

Oxford Energy owns 51% of the plant. General Electric billed the company for $40 million for plant construction. This was subject to a lawsuit and was reduced to approximately $22 million. The plant has two boilers, one above each travelling grate. The boilers were designed by Standardkessel GmbH which has an office in Greensburg, PA. The boilers produce 125,000 lbs/hr of 930 psig steam at 930°F which drive a single turbine/generator. The feedwater is preheated by the steam leaving the turbine. The plant can produce 15 MW of electric power of which they sell 12.4 MW. They receive $0.08/kWh from the sale of power.

Tire Supply

Initially there were 15 million tires in a stockpile at the plant site which assured a secure feed supply. The landowner had collected tires for many years. Until recently the plant paid 33 cents/tire for the tires processed. There is still a reserve of 3.5 million after reducing the stockpile since start-up in 1987. They have been processing 5 million tires per year which has cost $1.5 million.

Oxford Energy Company collects 7-8 million tires per year selling 20-30% of them for recapping. They pay $0.50/tire.

The Plant Manager emphasized the need to secure the supply of tires before beginning to build the plant. The feed rate of tires into the plant is up to 18000 per day. Each tire produces on average 20.1 kWh electric power. Plant revenue from power sales amounts to $9-10 million per year.

California charges a $2 tire tax at time of sale, which is largely used for administrative purposes. Tire stores charge a $0.25 to $3 fee for disposing of used tires. Disposal at land fill sites, where allowed, ranges from $5 to $10 per tire.

The Modesto plant got a jump on the industry by capturing the market early. The Plant employs 40 people. It operates 350 days a year at 32.5% thermal efficiency.

Tire Handling

The plant has a complex system for conveying the tires from the valley floor up to the plant site several hundred feet above. This system consists of a fork lift to transfer tires to bins from which tires are fed onto a conveyor, through a singulator prior to moving up a steeply inclined conveyor. At the entrance to the plant the tires are transferred to a roundabout from which tires are ejected on computer demand to two conveyors leading to the twin furnaces. Hydraulically operated flapper valves control the timing of the injection of tires onto the travelling grates in the furnace. The lockhopper opening is 12x48 inches which sets limits on the size of tire which can be fed. The grate travels rapidly at first and then more slowly when the tires have been largely consumed so that a total residence time of about two hours is achieved. This assures fairly complete burning of the carbon in the tires.

The conveyors have proven to be the greatest problem in operating the plant, particularly those which are operated on an intermittent basis.

Furnace Operation

The slag which drops from the furnace grate is collected and

stored at the site. It is planned to crush it and to remove the steel magnetically with an expected value for the steel of $0.01 per pound. The slag contains a large fraction of unburned carbon. It would be of low value.

Dust carried with the furnace off-gases is passed into a bag house which has 2,500 Gore-Tex bags made by Gore and Associates, Elkton, Md. These bags are more than 99.975% efficient in removal of dust particles as small as one ten thousandth of an inch in size. The flow through the bags is reversed every six hours to cause the collected solids to precipitate to the collection system at the base of the units. These solids are removed from time to time by truck.

Gases which have passed through the bags pass into a vessel into which an aqueous solution of calcium hydroxide is sprayed. The calcium hydroxide reacts with the sulphur dioxide in the gas forming calcium sulphite which oxidizes further in the air to yield calcium sulphate (gypsum) which is sold as a soil conditioner.

Stack Effluents

Some 200 pounds per day of sulphur dioxide is produced while the limit allowed by the state is 250 lbs/day (0.011 lbs/tire)

The plant's limit on NO_x was set at zero. The plant bought an 'offset' of 500 pounds of NO_x. The plant produces 450 pounds of NO_x so is within this limit. The plant manager states that NO_x can be controlled by spraying a urea-water solution into the hot gases in the furnace. This is more effective than the use of ammonia.

STACK EMISSIONS AT THE MODESTO POWER PLANT
(pounds per day)

	Limit	Operation
CO	340	110 (spikes to 550)
SO_2	250	200
NO_x	500(off-set)	450
Particulates	113	.03 (40% zinc)

In the event of a change in the plant, the new emissions would be:

EMISSION SPECIES	POUNDS PER DAY	COMMENTS
NO_x	250	By Off-Sets
CO	500	
SO_2	0	Will have to buy Off-Sets
Particulates	80	
HC	148	

Occasional tire jams cause fuel loss, and the air flow cools the flame and increases CO in the combustion gases. The stack plume is invisible except in winter due to moisture from the wet scrubbing. There was no sign of any visible emissions at the plant during the visit.

A discussion was held on burning tires in cement plants. It was stated that this is done extensively in Japan without pollution controls. It was stated that the Calaveras Cement Plant feeds tire chips but do not monitor emissions to the same extent as Modesto. It was suggested that cement plants may have to stop burning tires with the expected new regulations. It was stated that Cement plants already have high particulates.

Security and Fires

The plant is not visible from the highway and access is secured at a guard house three miles from the site. The company keeps a low profile due to concern about arson. Foam is available for fighting fires. In the future, a concrete catch basin will be built to store tires, which can be flooded in the event of a fire.

Economics of the Modesto Plant

Revenue	Tire Processing Fee	Product Value	Total
	0.50	1.80	2.30
Expenditure	Operating Cost	Capital Costs	Total
	1.00*	1.30	2.30

*1992, after release from $1.5 M/year to the landowner
Energy Sales - $9 M year (from 5 M tires/year)

Comments on the Incineration of Plastics

The Plant Manager, when asked about the possible use of plastic waste materials as feedstocks, was quite negative because of the problems which would arise due to the chlorine and HCl from PVC, as well as PCB's and dioxins. He thought that an elaborate scrubbing and monitoring system would be required to handle these materials without creating environmental problems.

Possible New Technology

The plant is not able to handle large truck tires. It has been suggested that these tires be cut up by means of a laser beam. This could be done in such a way that the off-gases would be passed through the furnace to incinerate any organic materials produced.

2. CALAVERAS CEMENT PLANT

Date: June 11, 1992

Location: Redding, California

Attendees: Bill Siemering, Plant Manager
Michael Bungay, CemEnergy
C.W. Bowman
E.L. Tollefson

Introduction

The Calaveras plant has been feeding tires since 1989, and whole tires since September 1991. They are about to feed their one millionth whole tire. They currently feed 1.7 to 1.8 million tires /year, representing about 20-22% of the energy requirements of the plant. The shredded tire feed-line is available if needed. Tires are collected from an area of about 200 miles around the plant. They have a network of suppliers, each with a "franchised" region. A 1000 tire trailer is left at a supplier's site if it can be filled within three weeks.

The landfill disposal fee is $2.00 near San Francisco and 30 to 40 cents in rural areas. Michael runs the supply system and provides "just-in time" inventory. We saw 2 or 3 trailers being unloaded onto the tire feed conveyor at the plant site, equivalent to about 2000-3000 tires.

The size of the feed entry to the kiln is 14"x 48".

Economics

Fuel costs are currently about $2 per million BTU, similar to coal. However, they quoted that the fuel value for tires was 90 cents per million BTU. Bill noted this was equivalent to 22 cents per tire fuel saving. The operating cost of handling tires after they have arrived at the plant is 40 cents per tire.

Transportation costs are $1.20/mile (both ways) for trucks with 10 tons of tires, which results in a transportation cost ranging from $3 to $28 per ton. (For example, a 100 mile return haul would cost $240 for 1000 tires or 24 cents/tire.)

They estimate the heat content of the average tire is 12,405 BTU per lb., lower than most estimates.

There are 6 cement plants feeding tires, 3 of which are fully meeting cement plant regulations, but more are coming on line rapidly. They stated that the capital costs for power plants feeding tires such as at Modesto are higher than for coal-fired plants. They do not believe tires will be directed to pyrolysis plants due to poor economics. Rough shredding costs are $40 per short ton.

It was stated that a used tire rebate fee would not be effective at the consumer level since only a few tires (and a few dollars) would be involved. However, a trucker who can handle 1000 tires/load can make a business out of this operation. Dealers who have to get rid of their stockpile also have an incentive to participate.

Michael Bungay asked about Alberta's objective - is it to develop technology or to get rid of tires?

Environmental Aspects

Reference was made to a California government report which stated that emissions were similar with or without tire feed when coal was used as the main energy source.

The plant does periodic assessments for carcinogenic compounds and heavy metals. They have not detected any change in zinc or carbon levels with or without tires. SO_2 content is essentially zero. They have a high CO limit set by the County and approved by the State.

Computer records of emissions were provided to the Reviewers.

They do not wish to handle chlorine-containing plastics due to emissions and deposit formation.

It was observed that the stack above the precalciner unit was clean. One would not know that the plant was operating since there was no plume. The temperature was approximately 65-70° F and the day was relatively dry.

STACK EMISSIONS - CALAVERAS CEMENT PLANT

	Permit Conditions	June 11, 1992 Data
SO_2	20 ppm	
NO_x	2.75 lbs/ton clinker 350 ppm	100-200 ppm
Particulates	17.9 lbs/ton	
CO	2500 ppm	200-1500 ppm

3. CONRAD INDUSTRIES INC.

Date: June 12, 1992

Location: Centralia, Washington

Attendees: William F. Conrad, President
Philip Bridges, Vice-President
C.W. Bowman
E.L. Tollefson

Introduction

Bill Conrad and Phil Bridges gave the impression that they are both innovative entrepreneurs trying largely to develop pyrolysis technology for sale. Since March 1986 when the plant was first started, they have experimented with many different feedstocks, including plastics. The plant for the most part now runs five days per week on a 24 hour per day basis. While it is said to be a "commercial" operation, in view of the intermittent operation and the evaluation of various feedstocks, the plant appears to serve primarily as a large scale pilot plant. It can handle, for example, 100 tires per hour (1 ton per hour) of 2-inch tire chips as feedstock. They consider that what pyrolysis accomplishes is close to what the EPA strives for, as expressed by the phrase "in the highest and best use". Other processes destroy the carbon values in tires.

They buy shredded tires, either at no cost or with a modest payment for disposal.

About 80% of the pyrolysis work which is done in the plant is on tires, while 20% is with other feedstocks. In their opinion, pyrolysis should be used for difficult to handle residues. They consider that their pyrolysis system has evolved considerably and that it is unique in several respects. Phil Bridges described pyrolysis as a form of "molecular engineering." Besides pyrolysing tires, they have processed:

(a) shredded auto residues containing plastics and rubber;
(b) oil sands;
(c) drilling muds;
(d) materials such as commingled plastic chips; and
(e) materials recovered from hazardous waste sites.

Bill Conrad pointed out that the economics in terms of plant capital costs depend upon what specific operations need to be included in order to operate the plant. Pyrolysis systems require shredded tires which are expensive in terms of equipment and power requirements. (The technology has not yet advanced to the point in which whole tires can be employed as feedstock.) Upgrading is required to obtain higher prices for the product carbon. Upgrading can be expensive depending upon the steps which need to be taken and the instruments and manpower required to suit the qualities of the products made.

Plant Location

They pointed out that plant location is a very important factor in terms of the supplies of raw materials and the markets for the products. Efforts must be made to optimize these factors in terms of the profitability of the plant.

Products of Pyrolysis

The products of pyrolysis are:

(a) gaseous vapour which may be used to provide heat for the pyrolysis of the feed;

(b) oils which have a wide range of boiling points from materials such as toluene through diesel and fuel oil fractions;

(c) carbon which needs to be upgraded to increase its value; and

(d) metals which can be sold to scrap metal dealers.

It was their opinion that unless the plant was quite large, it would not pay to upgrade the gas or oil products, except perhaps to remove sulphur compounds so that they would be more readily sold. Several fractions could be produced from the oil, but it would be better to sell these fractions to a refinery, if possible, than to build a distillation unit.

The carbon constitutes a large fraction of the product. Conrad

and Bridges have developed methods for upgrading carbon by acid washing and other techniques such as activation. Apparently the carbon as recovered has a significant surface area as indicated by iodine numbers ranging from 100 to 200. It could be used in purification of water or to sorb oil out of water since it is quite oleophilic. The value of the carbon fraction appears to determine the profitability of the process.

Tipping Fees

Conrad and Bridges seemed reluctant to talk openly about tipping fees saying that each state or region was different depending upon existing conditions. When asked who paid the tipping fee, they finally agreed that it is almost universal that the customer pays it, although the fee may be buried in the price paid for a new tire.

The dealer pays the trucker to take the tires to a shredder and have them reduced to 2-inch chips. These chips are delivered to Conrad Industries Inc. for pyrolysis. Conrad does not pay for the chips. They have only one associate who does the shredding for them. The exact nature of the collection system was not discussed in detail.

Operation of the Plant

The plant was not operating during the visit but appeared to be capable of doing so.

The plant is well laid out and compact in design. There was a pile of shredded tires in the yard.

It was noted that materials handling was a major plant issue, both for feedstocks and products.

Product oil was stored in tanks on site. Steel and fibres are separated from the carbon prior to bagging. Stainless alloys are used to prevent corrosion (the presence of carbon protected the retorts).

When asked about coking problems Mr. Conrad replied that they have had no coke or tar problems in the operation of the plant. The plant is built in such a way that it is readily serviced should problems arise. They are building a new feed system to

avoid precipitation of materials around the inlet to the "auger" which requires reaming to prevent blockage. Mr. Conrad noted that it is not an auger, but rather a shaft with paddles. They are pleased with the instrumentation and controls which they have installed to follow the operation of the plant.

A pyrolysis unit, being largely a closed one, requires relatively few controls compared to incineration where effluents must be continuously monitored.

Values of Products from Pyrolysis

Phil Bridges noted that market availability for the product will drive pyrolysis. The market for the carbon product is good. They get $0.10 to $0.20 per pound (U.S.) without upgrading. As fuel, it would sell for $0.05 per pound. He thought that with suitable upgrading, for example by acid leaching, it may be possible to get $0.35 per pound.

The carbon contains some zinc and sulphur, so farmers have found that it can increase crop yields by 10% in some cases when applied at the rate of 300 to 400 pounds per acre.

It is difficult to get the tire manufacturers to adopt the recycled carbon in their operations. They have prejudice against the use of new materials and tend to stick to well-known materials. Some of the carbon is used in pigments in rubbers and various plastic articles.

The oil product has been selling for $0.25 to $0.50 per gallon (U.S.). If the light ends are fractionated, the volatile fraction containing considerable toluene will sell for up to $0.50 per gallon. Plant location is important in being able to sell these products. The metals may not sell well depending upon local conditions, but may sell for as high as $40 to $50 a ton.

General Observations

Pyrolysis is a developing technology which is best applied to residues which are generally of low value. The technology is versatile and can handle many types of feedstocks. At this time, waste tires are being used largely as the feedstock, but it is considered that the glut of waste tires will be consumed in the

U.S.A. in the next few years. Depending upon economic and market forces only a few operators will be required to consume the waste tires being produced, estimated to be one per person per year.

For pyrolysis to become more profitable, upgrading of the product carbon is necessary. Upgrading of the vapour and oil product streams is not considered economically feasible.

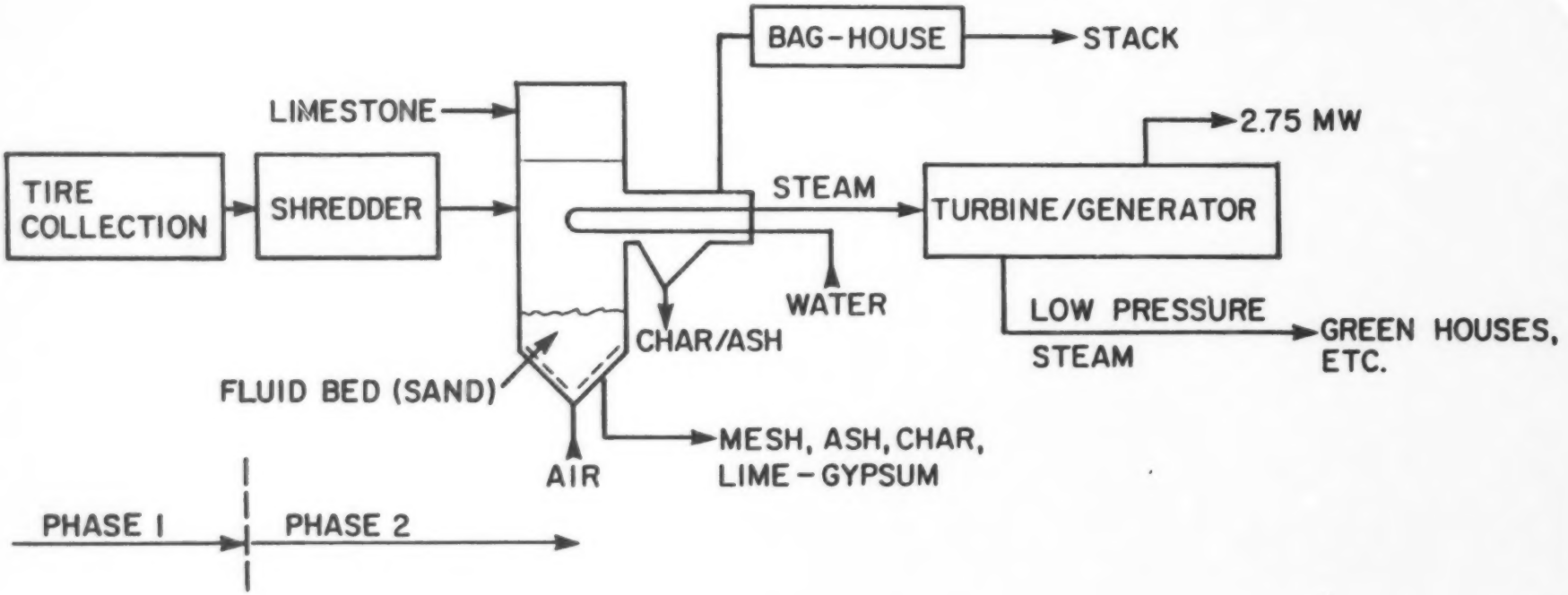
Operation of a pyrolysis unit requires less monitoring and fewer controls to meet environmental standards than does processing in kilns, in fluid bed units or on travelling grates. Pyrolysis must still be considered to be in an advanced pilot plant stage.

APPENDIX C- PROCESS FLOW CHARTS

This section contains simplified flow charts of each project prepared by the Reviewers to assist in process evaluation. These are meant to illustrate key process steps, and have not been verified by the Proponents.

FLOW SYSTEM FOR PACIFIC INTEGRATED WASTE SYSTEMS PROPOSAL

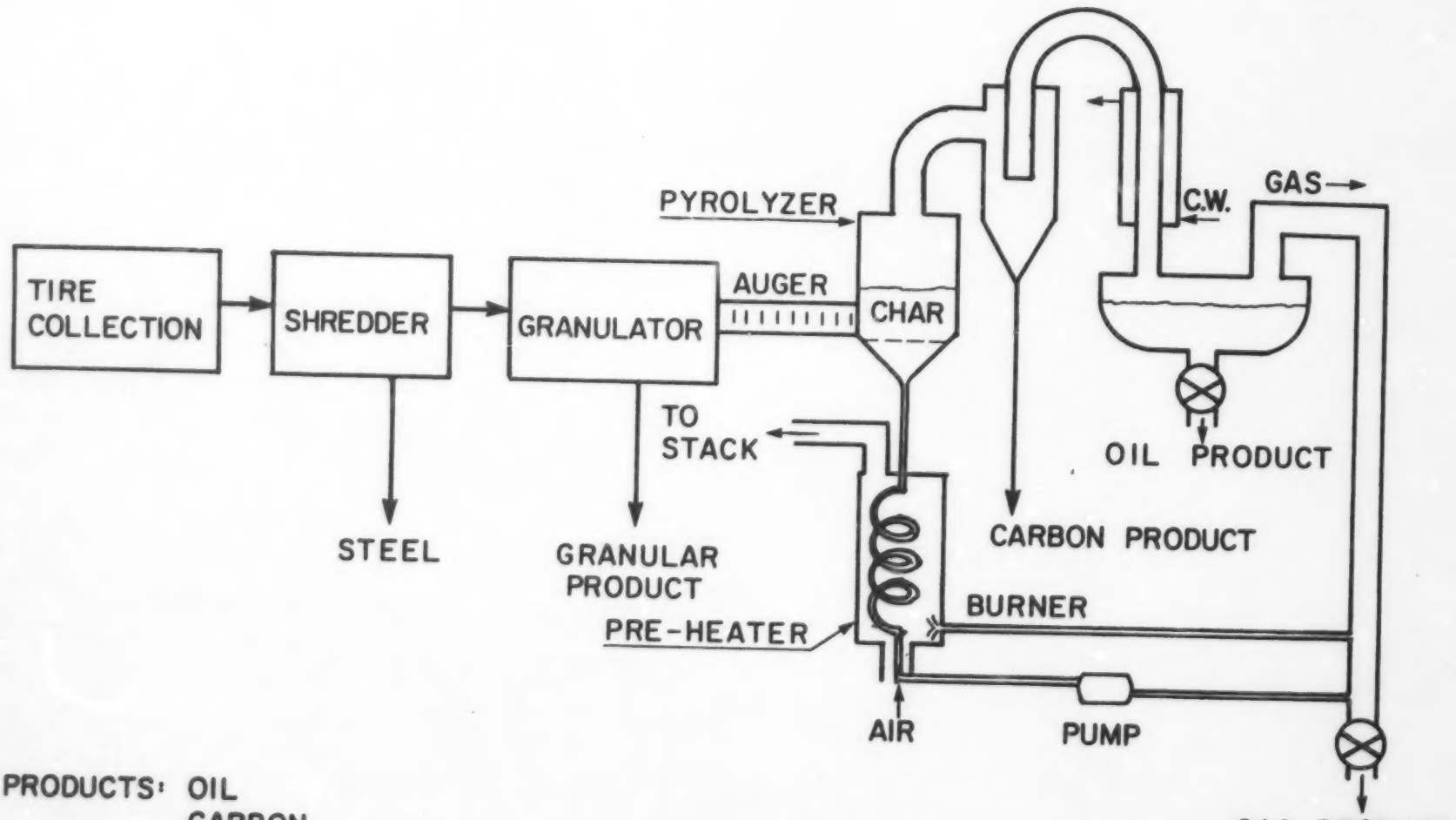
1.5 MILLION TIRES PER YEAR



PRODUCTS:
1. ELECTRIC POWER = 2.75 MW
2. LIME/ASH/CHAR/GYPSUM (SOIL CONDITIONER)
3. MESH STEEL AND BEAD → METAL SALES
4. STEAM FOR HEATING PURPOSES

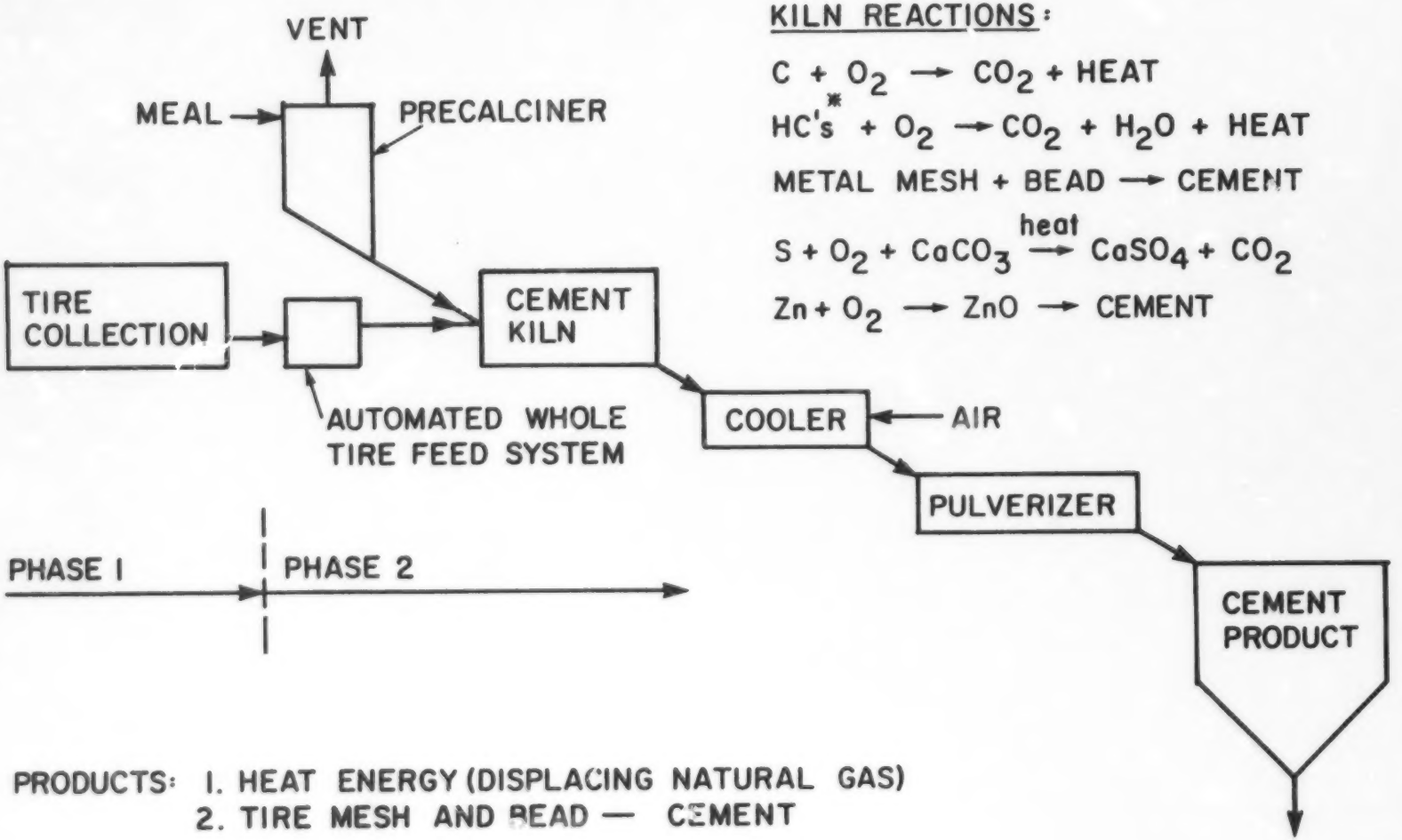
FLOW SYSTEM FOR WORTHING INDUSTRIES INC. PROPOSAL

YEAR I – 310,000 P.T.E.



PRODUCTS: OIL
CARBON
GAS
STEEL

FLOW SYSTEM FOR INLAND CEMENT LIMITED AND LAFARGE CANADA INC. PROPOSALS



KILN REACTIONS:

$C + O_2 \rightarrow CO_2 + HEAT$

$HC's^{*} + O_2 \rightarrow CO_2 + H_2O + HEAT$

METAL MESH + BEAD $\rightarrow$ CEMENT

$S + O_2 + CaCO_3 \xrightarrow{heat} CaSO_4 + CO_2$

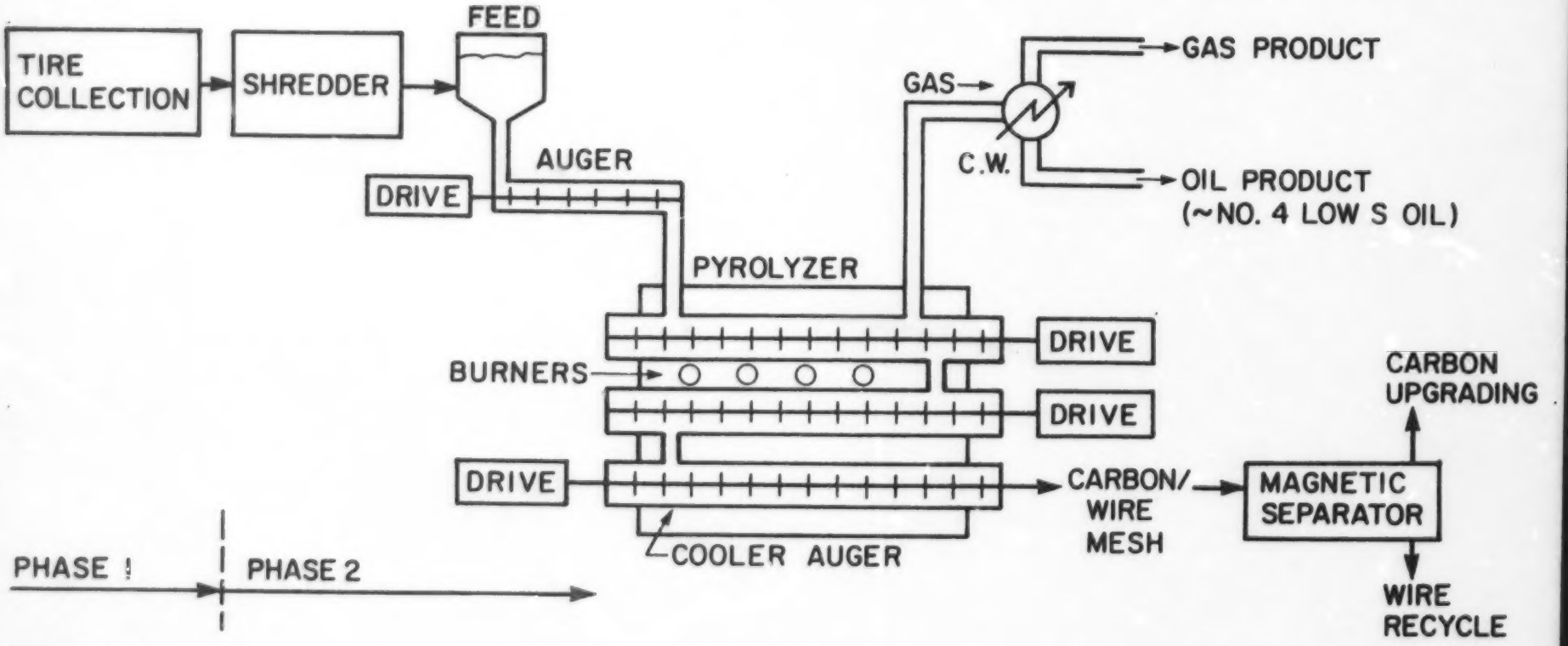
$Zn + O_2 \rightarrow ZnO \rightarrow$ CEMENT

PRODUCTS: 1. HEAT ENERGY (DISPLACING NATURAL GAS)
2. TIRE MESH AND BEAD — CEMENT

* HC's = HYDROCARBONS IN RUBBER

FLOW SYSTEM FOR ENERWASTE INTERNATIONAL INC. PROPOSAL

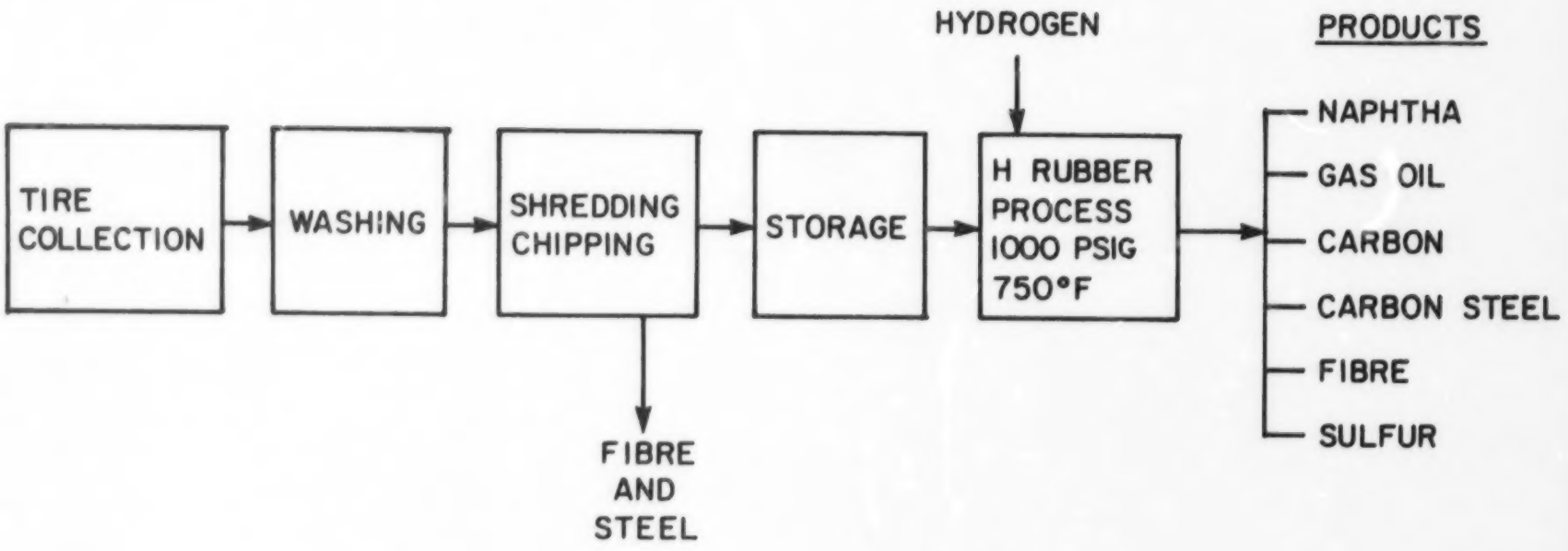
1.5 MILLION TIRES PER YEAR



PRODUCTS:			
	OIL	50%	TO REFINERY FOR UPGRADING
	GAS	10%	TO BURNER OR SALES
	CARBON	32%	TO UPGRADING AND SALES
	STEEL	7%	TO METAL RECYCLING

FLOW SYSTEM FOR THE HUSKY OIL-CANA PROPOSAL

2.5 MILLION TIRES PER YEAR



APPENDIX D- ADDITIONAL REVIEW OF FOUR PREVIOUSLY REJECTED PROPOSALS.

Alberta Environment requested that the Consultants review four additional pyrolysis projects, which met the mandatory requirements of the RFP, but which had been rejected by the Advisory Committees. The purpose of this further review was to ensure that all pyrolysis proposals were subjected to a uniform evaluation process. The following are brief comments by the Consultants regarding these four proposals

1. 385047 Alberta Limited

This project would send a mobile shredder to various tire stockpiles throughout the province, and truck the shredded material to a central pyrolysis plant. The latter would be based on the process developed by Cleaner Products and Conrad Industries Inc. Details of the tire collection system are scanty, and the proponents have little direct experience with pyrolysis technologies. The proposal does not measure up to similar concepts which received the approval of the Committees. The Reviewers do not recommend that this proposal receive further evaluation at this time.

2. Pacific Aqua-Tech Limited

This project involves the use of an electrically-heated retort, originally developed for wood waste. The use of electricity as a heat source is relatively inefficient and reduces the option of utilizing part of the off-gas as fuel. How the off-gas is to be handled is unclear. The capital cost is high. The tire collection approach is not well covered. This is not a well-integrated proposal and the Reviewers do not recommend that this project receive further evaluation at this time.

3. TAREM

This project uses the Taciuk Processor as the pyrolysis system, which has had only limited testing on rubber tires. The concept is based on a portable processing unit, periodically transported to several marshalling sites. This would give rise to complex siting and product disposal problems. If UMATAC and TAREM had developed a single integrated proposal, it would probably have been better, but in the opinion of the Reviewers, would unlikely

have met the standards set by the Committees. The Reviewers do not recommend this proposal receive further evaluation at this time.

4. Surety Environmental Inc.

This project involves shredding tires at various transfer sites, and then trucking the shredded material to two storage and pyrolysis centres at Camrose and Strathmore. In one document, the pyrolysis process uses superheated steam as the heating and mixing medium. There are no references to this being a commercially available process or any information on its past performance. In another document, reference is made to an unnamed Japanese developed and Korean manufactured pyrolysis process. The Reviewers do not recommend that the proposal be further evaluated at this time.

APPENDIX E- TERMS OF REFERENCE OF REVIEW PROCESS

TASK 1. CONSULTANTS INITIAL REVIEW

1.1 Review and analyze each proposal
1.1 Review reports of previous committees

TASK 2. FIRST MEETINGS WITH ALBERTA ENVIRONMENT

2.1 Discuss objectives and timetable
2.2 Discuss and agree on project methodology
2.3 Discuss and agree on structure of recommendations

TASK 3. CONSULTANTS JOINT WORK SESSION

3.1 Discuss and compare information on each proposal
3.2 Identify key criteria for "horizontal" analysis of the proposals
3.3 Compare proposals across key elements
3.4 Identify missing information
3.5 Develop schedule for meeting with proponents

TASK 4. MEETING WITH PROPONENTS

4.1 Prepare format and questions for each proponent
4.2 Meet with each proponent
4.3 Prepare summary of findings from each meeting

TASK 5. POST MEETING FOLLOW-UPS

5.1 Meet with two engineers involved in current incineration/pyrolysis work to confirm most recent state of development of technology and to obtain an assessment of likely risks and possible delays in commercialization

5.2 Visit one incineration and one pyrolysis commercial site and obtain capital costs, operating costs and service factor data

TASK 6. CONSULTANTS JOINT WORK SESSION

6.1 Finalize list of findings from preceding work
6.2 Prepare list of recommendations
6.3 Prepare report outline
6.4 Prepare draft report
6.5 Meet with Ministerial Advisory Committee

TASK 7. FINAL MEETING WITH ALBERTA ENVIRONMENT

7.1 Present draft report and discuss findings and recommendations
7.2 Discuss any missing information in the draft report

TASK 8. FINAL REPORT PREPARATION

8.1 Prepare and bind six copies of final report
8.3 Forward required number of copies to Alberta Environment